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JUPITER'S SATELLITES VISIBLE TO THE NAKED EYE.

T. J. J. SEE.

FOR POPULAR ASTRONOMY.

The claim has occasionally been made by observers that some of Jupiter's satellites are now and then visible to the naked eye, and a few cases are on record showing apparently that the reports are authentic; yet I am not sure that astronomers in general have acquiesced in the reality of the phenomena said to have been noticed by persons of unusual acuteness of vision. Professor Eastman of the Naval Observatory at Washington mentioned to the writer in a recent conversation that he had found the satellites visible to the naked eye when in Colorado some years ago, and suggested that an examination be made to show whether they are not visible in the steady atmosphere of Arizona. During the months of April and May more than twenty days after the opposition of Jupiter, which occurred March 25, I have made regular observations on nearly every available night; and though I have kept myself purposely in the dark as to their predicted positions, I have seen and drawn them regularly near their actual places, without recording more than two deceptions in some twenty trials. On the occasions when I was deceived, it was in respect to two closely adjacent satellites whose positions are easily confused by the twinkling, the others being given with their usual precision. Thus I have regularly seen the third satellite when distant from Jupiter more than 3′, and the second and fourth satellites have also been noted occasionally, though both of these bodies are very much more difficult than the third.

The first satellite, which is perhaps next to the third in brightness, I have never recognized with certainty, and on account of its closeness to Jupiter, we should hardly expect it to be visible even in the blackest and stillest sky.

The following table shows the maximum distance of the satellites from Jupiter, and also their magnitudes, as determined by my observations, on the standard scale used for stars.

Satellite	Distance from centre of Jupiter.	Magnitudes
I	2′ 27″	6.5
II	3′ 55″	6.6
III	6′ 15″	6.2
IV	11′ 2″	7.0

It will of course be understood that the distances of the satellites during my observations were always less than those given in this table, which correspond to an October opposition.

The third satellite frequently appeared very easy, and could be seen continuously and with perfect distinctness. I estimate that in absolute magnitude it is just a shade fainter than Uranus, though of course the latter, being projected in a black sky and free from a bright neighboring body such as Jupiter, is much more easily seen than any of the satellites.

As the second satellite is quite close to Jupiter and only moderately bright, while the fourth is very remote and excessively faint, both are extremely good tests of climatic conditions and sharpness of vision. It appears however from my observations that the fourth satellite is somewhat more difficult than the second. Indeed I consider the seeing of the obscure fourth a supreme test of vision. Though I did not make special searches for it I succeeded in recognizing this faint distant attendant on at least three nights during the interval of the observations.

It will of course be understood that all these trials were made without previous knowledge of the configurations of the satellites, and thus no effort was made to catch the satellites at the epochs of their maximum elongation. On several occasions, after locating the visible satellites on one side, I made a determined effort to imagine a possible satellite where I had seen none before; whatever be the experience of other observers in such matters, I found by these trials that I never deceived myself once.

It will be of interest to recall in this connection the previously reported visibility of these objects cited by a leading historical authority. In the *Cosmos* Vol. III, (pp. 50 to 53 of Bohn's Translation) Humboldt gives a very interesting account of objects visible to the naked eye, and mentions several cases of persons who could see difficult objects, including the satellites of Jupiter, without a telescope. He says: "As a remarkable instance of acute vision, and of the great sensibility of the retina in some individuals who are able to see Jupiter's satellites with the naked eye I may instance a case of a master tailor named Schön, who died at Breslau in 1837, and with reference to whom I have received some interesting communications from the learned and active director of the Breslau Observatory, Von Boguslawski. "After having (since 1820) convinced ourselves by several rigid tests, that in serene moonless nights Schön was able correctly to indicate the position of several of Jupiter's satellites at the same time, we spoke to him of the emanations and tails which ap-

peared to prevent others from seeing so clearly as he did, when he expressed his astonishment at these obstructing radiations. From the animated discussions between himself and the bystanders regarding the difficulty of seeing the satellites with the naked eye, the conclusion was obvious, that the planet and fixed stars must always appear to Schön like luminous points having no rays. He saw the third satellite the best, and the first very plainly when it was at the greatest digression, but he never saw the second and the fourth alone. When the air was not in a very favorable condition, the satellites appeared to him like faint streaks of light. He never mistook small fixed stars for satellites, probably on account of the scintillating and less constant light of the former. Some years before his death, Schön complained to me that his failing eyes could no longer distinguish Jupiter's satellites, whose position was only indicated, even in clear weather by light faint streaks."

The remark of Boguslawski quoted above to the effect that the satellites are more constant in their light and scintillate less than stars is misleading; it is certain that they frequently twinkle the same as if mere points devoid of measurable discs. Thus Uranus, which has a diameter of 4″, is now situated near the naked eye double, Omega Scorpii, and recently on several occasions I have noticed it twinkle just the same as the neighboring pair of stars, which are of the fifth magnitude. As the discs of Jupiter's satellites are much smaller than that of Uranus, they must scintillate much more frequently. Indeed while observing the third, I have noticed it scintillate just like a little star, and as this phenomenon was repeatedly observed, there cannot remain any doubt on this point.

Humboldt remarks that the rays or tails, which to our eyes appear to radiate from the planets and fixed stars, have been used since the earliest ages of mankind, and especially among the Egyptians, as pictorial representations to indicate the shining orbs of heaven, and are from five to six minutes in length. Hassenfratz shows that these rays are due to caustics * on the crys-

* On mentioning this point to a friend he suggested that the rays might be due to the irregularities of the outline of the pupil. On putting a series of diaphragms in which the holes are perfectly round, before my eye and looking at stars through them, I find that the wings or rays continue until a very small aperture is reached. With a diaphragm sensibly smaller than the pupil of the eye, the wings are still shown, but when the diameter of the aperture is about half a millimetre, all the rays disappear. In this way I see Jupiter and Venus perfectly round without a trace of a ray attached to them, and the same is true of stars. This experiment seems to show that the rays are due to caustics, the lens performing perfectly only when the available aperture is very small.

talline lens of the eye, and their extent is therefore different in different individuals.

The fifth magnitude star Alcor near Mizar in Ursa Major, was not noticed by the Greeks, and among the Arabians it was considered a test of the power of vision and called accordingly *the test, Saidak*, as we learn from the Persian Astronomer, Kazwini.

Humboldt remarks that notwithstanding the low position of the Great Bear under the tropics, he saw Alcor very distinctly with the naked eye, evening after evening, on the rainless shores of Cumana and on the plateaus of the cordilleras which are elevated nearly 13000 feet above the level of the sea, and that he saw it less frequently and less distinctly in Europe and in the dry Steppes of Northern Asia.

This object has never presented the least difficulty to me anywhere, and in Mexico as well as in Arizona, where it shows with such extraordinary brilliancy, I have often wondered how the Greeks could have overlooked an object which is so plain to every one. The limits within which two contiguous celestial objects can be separated, depend of course upon the relative brilliancy of the stars. The naked-eye pair Alpha Capricorni is separated over six minutes of arc, and I have always found that they are divided by unskilled observers. In the more southern region Delta Centauri is a much more severe test of vision, but notwithstanding its low altitude as seen from Mexico Mr. Cogshall and I always divide it without the least difficulty.

The celebrated quadruple or naked-eye double Epsilon Lyrae is a much better test of vision as respects the power of separating close equal objects. This pair is separated by 204″ or nearly 3.5 minutes, and by persons of keen sight is seen divided or elongated. I have examined it many times in Europe as well as in America, always seeing it plainly double, and under good atmospheric conditions have never failed to recognize a distinct black line between the components about as wide as the spurious images of the stars. When the heavens are in a moderately good condition, in my opinion, the recognition of the duplicity of this object is not difficult. Judging by tests made on this star I infer that sharp eyesight could distinguish the duplicity of such an equal double separated by about half the distance, or something like 100″ of arc. From this consideration it is clear that the first satellite of Jupiter would be separable with the naked eye, except for the extreme inequality of the two images allowing the rays which radiate from the brilliant planet to obscure its faint attendant. It is of course possible to see closer objects of a terres-

trial character in a laboratory, because in this case there are no atmospheric disturbances which increase the size of the spurious discs, and thus tend to amalgamate the two images seen in the sky. The minimum optical angle at which terrestrial objects can be seen depends upon their form, lines being much more easily recognized than mere spots, on account of the wider extent of the retina covered by the respective images. Hook fixed the distance at which black spots on white paper could be recognized at a minute; Tobias Mayer could see them at 34″, and more recent experiments have reduced the distances very considerably. The irradiation, however, must be taken into account, and thus in any given case the color and nature of the illumination, as well as the eye of the observer, modifies the result. Humboldt mentions the astonishment he once felt near Quito when the Indian guides recognized his companion Bonpland at such a distance that the angular diameters of his cloak was 7″ and 12″, yet when his mantle was projected against the black basaltic side of a volcano it was distinctly recognized as a white moving speck.

Experiments on contiguous illuminated spider lines show that they can be separated by the naked eye when separated by much less than a second of arc. This result as to the distinct visibility of lines so close that corresponding spots would be altogether indistinguishable is of importance in connection with the study of the Martian canals, and of their duplication. In the case of Mars, however, the parallel lines are always seen in a telescope and therefore under moderately high magnifying power.

LOWELL OBSERVATORY, Flagstaff, Ariz.,
1898, May 28.

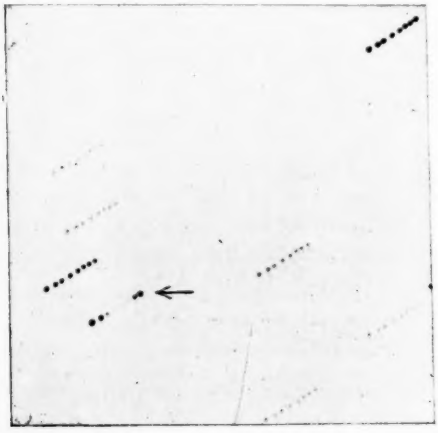
NOTE.—Since the foregoing was written Professor Barnard has paid us a visit at the Observatory, and tells me that Professor George Davidson of San Francisco has frequently seen the satellites of Jupiter in the clear atmosphere of the high Sierras. Though the Moon was very bright and the weather unfavorable during Professor Barnard's visit, both he and I recognized the third satellite on two evenings. I could on one night recognize also the second, but it was on the limit of vision.

LOWELL OBSERVATORY,
1898, June 6.

VARIABLE STARS OF SHORT PERIOD.

EDWARD C. PICKERING.

Whoever will make a careful examination of the brightness of a large number of stars either in the sky, or better as photographed upon different plates, will be impressed with the vast number which show no perceptible variation. The discovery of variable stars is greatly aided when we are able to make a suitable selection for examination, either from their spectra or from their presence in clusters. Visually, we can never be sure that all the variables in a given region have been found, however carefully we may study them. Photography brings this problem more nearly within our reach, and a partial solution of it is illustrated in the accompanying figure. A photographic telescope



was constructed having as an objective a Cooke Anastigmatic Lens with an aperture of 2.6 cm. and a focal length of 33.3 cm. This telescope was mounted equatorially and the lens was alternately exposed and covered for intervals of exactly 10 and 50 minutes by an electrical attachment. The polar axis of the mounting was displaced and the rate of the driving clock was increased, so that the successive images should be slightly separated. An 8×10 photographic plate was exposed in this instrument on April 21, 1898, and eight successive images were obtained, the Greenwich Mean Times of the middle of the exposures

being $13^h\ 49^m$, $14^h\ 49^m$, $15^h\ 49^m$, $16^h\ 49^m$, $17^h\ 49^m$, $18^h\ 48^m$, $19^h\ 48^m$, and $20^h\ 48^m$. The plate covered a region about 33° square, whose centre was R. A. $= 1^h\ 2^m$, Decl. $= +\ 76°.6$. The images of the stars in the corners of the plate were sufficiently good when visible to show very slight variations in light, but owing to their increased size the faintest stars were not shown. The greatest loss amounted to about one magnitude. If now any variable star having a period of less than 14 hours was contained in this region it is probable that at least one maximum and one minimum would be photographed. The figure represents a portion of the plate described above, enlarged ten times to a scale of $60'' = 0.1$ cm., and covers about one square degree. It therefore represents one thousandth of the entire plate, the size of which on this scale would be two meters, or nearly seven feet square. The entire sky, from the north to the south pole, could be covered by forty such plates, and it is proposed to do this as soon as the best method of taking the plates has been determined. The arrow indicates the variable star U Cephei, and its photometric magnitudes at the times the eight images were taken were 7.5, 8.1, 8.9, 9.1, 9.1, 8.3, 7.6 and 7.2. The three stars above it are + 81° 30, + 81° 27, and + 81° 29, which have the photometric magnitudes 7.9, 8.5, and 8.6. To separate the successive images various methods have been tried. The best of these seems to be stopping the driving clock for a few seconds every hour. By the above plan we hope to secure a complete list of all variable stars of short period brighter than the ninth magnitude at maximum whose variation exceeds half a magnitude and whose period is less than a day. Doubtless, many other variable stars of longer period, and stars of the Algol type may also be incidentally found.

May 21, 1898, Circular No. 29,

HARVARD COLLEGE OBSERVATORY.

THE ASTRONOMY OF SHAKESPEARE.

ORRIN E. HARMON.

FOR POPULAR ASTRONOMY.

THE PLANETS.—Shakespeare's allusions to the planets are very often made astrologically. In but few instances are they made from a purely astronomical point of view.

In the following passage he expresses the prevailing idea of the time, that the earth is the centre about which the planets revolve

* Continued from p. 241.

at the same time coloring his idea with the fancies of astrology:

" The heavens themselves, the planets and this centre,
Observe degree, priority and place,
Insisture, course, proportion, season, form,
Office and custom, in all line of order;
And therefore is the glorious planet Sol
In noble eminence enthron'd and spher'd
Amidst the other; whose medicinable eye
Corrects the ill aspects of planets evil,
And posts, like the commandment of a King
Sans check to good and bad."
Troilus and Cressida, Act I, Sc.III.

While presenting the Ptolemaic idea of the planetary system, Shakespeare, in the above lines, touches upon the law and harmony of the heavens with great beauty.

In our consideration of the planets, the earth will be noticed first, then the other planets in regular order.

THE EARTH.—That the Earth is spherical in shape, is prominent in Shakespeare's writings. In those famous lines in which the destruction of the Earth and its contents is stated with marvelous force, he says,

" The great *globe* itself,
Yea, all which it inherit, shall dissolve, etc."
Tempest, Act IV, Se. I.

Also in the following passage the Earth is spoken of as a globe:

" We the *globe* can compass soon
Swifter than the wandering moon,"
Midsummer Night's Dream, Act IV, Sc. I.

Poor King Lear, the victim of his daughter's ingratitude, standing in the heath, cold and shelterless, cries out amidst the raging thunder storm:

"And thou all-shaking thunder,
Smite flat the thick *rotundity* o' th' world."
Lear, Act III, Sc. II.

The illumination by the Sun of one-half the Earth at a time, is shown by the following reference:

"Now o'er the one-half world
Nature seems dead, and wicked dreams abuse
The curtained sleep." Macbeth, Act II, Sc. I.

Shakespeare knew that there is a place on the Earth called the "North Pole." Probably it did not attract the attention in his day that it does now. However, one of his characters in the dialogue below, thought the north pole an affair of some importance:

"Armado.—By the north pole, I do challenge thee.
Castard.—I will not fight with a pole like a northern man: I'll slash; I'll do it by the sword." Love's Labor's Lost, Act V, Sc. II.

While speaking of the Earth, it may not be improper to digress a little from the astronomical phase of our subject, and inquire into Shakespeare's knowledge of the geography of the Earth. It is of some importance to learn what he knew of our planet—its countries, mountains, rivers, etc. Of course, no special mention need be made of those countries in which the scenes of the plays are laid. I shall speak mostly of the places foreign to the scenes of the plays.

Shakespeare understood the use of a *map*. Knew not only what it meant, but *what it meant by the discovery of the new world*.

"He does smile his face into more lines than is in the *new map* with the augmentation of the Indies." Twelfth Night, Act III, Sc. II.

We shall soon see that he knew not only of the Indies, but of the *East* and the *West* Indies.

I will now give some of the countries noticed by Shakespeare, and the play where mentioned.

America, Spain, Belgia (Netherlands), Poland.
Comedy of Errors, Act III, Sc. II.

This is the only mention of America made by Shakespeare.

Arabia.—Tempest, Act III, Sc. III. Also in Troilus and Cressida, Macbeth, and Merchant of Venice.

India.—Midsummer Night's Dream, Act II, Sc. I, and in First Part of Henry IV.

Tripolis, Mexico, Barbary, Lisbon.
Merchant of Venice, Act I, Sc. III.

Russia.—Winter's Tale, Act III, Sc. II, and in Macbeth.

Lapland.—Comedy of Errors, Act IV, Sc. III.

Macedon.—Henry V, Act IV, Sc. VII.

Syria.—Antony and Cleopatra, Act I, Sc. II.

East and West Indies—Guiana—Merry Wives of Windsor, Act I, Sc. III.

It will be seen by consulting the references to the Indies that Shakespeare shared the common belief of the time that the Indies were fabulously rich countries and especially the West Indies. This appears further by the following passage:

"Had Henry got an empire by his marriage,
And all the wealthy kingdoms of the west,
There's reason he should be displeased at it."
Second Part Henry VI, Act I, Sc. I.

Also Shakespeare hints something more about the extent of the discoveries that were being made in his day:

"One inch of delay more is a South-Sea of discovery."
As You Like It, Act III, Sc. II.

Among the mountain ranges noticed by Shakespeare, are the Alps, Apennines and Caucasus.

"I would allow him odds,
And meet him, were I tied to run afoot
Even to the frozen ridges of the Alps."
Richard II, Act I, Sc. I.

The same mountain range is noticed in Henry V, Antony and Cleopatra, and King John. In the last play (Act I, Sc. I) the Apennines and River Po are referred to.

Bolingbroke says:

"O, who could hold a fire in his hand
By thinking on the frosty Caucasus?"
Richard II, Act I, Sc. III.

Shakespeare also speaks of Mount Ætna:

"Now let hot Ætna cool in Sicily,
And be my heart an ever burning hell."
Titus Andronicus, Act III, Sc. I.

The same mountain is referred to in The Merry Wives of Windsor and in Lucrece.

This mention of rivers is quite limited. The Thames is noticed several times.

The Euphrates—Antony and Cleopatra, Act I, Sc. III.
The Nile—Titus Andronicus, Act III, Sc. II, and in Antony and Cleopatra, Act II, Sc. VII.

In his references to the river Nile, he also speaks of its overflow.

We will now step off the Earth, and survey the other planets.

MERCURY.—This planet is spoken of many times in its mythological relation, only once in its planetary character. Even in this one mention its astrological feature predominates.

"My father named me Autolycus, who being, as I am, litter'd under Mercury was likewise a snapper-up of unconsidered trifles."
Winter's Tale, Act IV, Sc. III.

VENUS.—While very prominent in Shakespeare's plays in her mythological vesture, Venus also stands out clearly as a planet.

"Yet you, the murderer, look as bright, as clear,
As yonder Venus in her glimmering sphere."
Midsummer Night's Dream, Act III, Sc. II.

And again in the same play, act and scene is found the following:

"Flower of this purple dye,
Hit with Cupid's archery,
Sink in apple of his eye,
When his love he doth espy
Let her shine as gloriously
As the Venus of the sky."

MARS.—The red color of Mars was early known, and quite natural it was that he should be worshipped as the god of war.

Shakespeare makes frequent reference to him in this character. But even more interesting are his allusions to Mars as a planet. The motions of the planet were perplexing to astronomers in Shakespeare's day.

It is well known that Kepler chose this planet as the chief object of his study from which sprung his great planetary laws.

Shakespeare makes pointed reference to the mysterious movements of Mars.

Charles, the Dauphin, before Orleans says:

> "Mars, his true moving, even as in the heavens
> So in the Earth, to this day is not known."
> First Part Henry VI, Act I, Sc. II.

The retrograde motion of the planets is finely illustrated in the following dialogue concerning Mars:

> "*Helena*—Monsieur Porolles, you were born under a charitable star.
> *Porolles.*—Under Mars, I.
> *Helena.*—I especially think under Mars.
> *Porolles.*—Why under Mars?
> *Helena.*—The wars have so kept you under that you must needs be born under Mars.
> *Porolles.*—When he was predominant.
> *Helena*—When he was retrograde, I think, rather.
> *Porolles.*—Why think you so?
> *Helena.*—You go so much backward when you fight."
> All's Well That Ends Well, Act I, Sc. I.

JUPITER—Though mentioned many times, Jupiter, with one exception, is always spoken of mythologically. Even then astrology causes the planetary allusion:

> "Our Jovial star reign'd at his birth and in
> Our temple was he married."
> Cymbelline, Act V, Sc. IV.

It is very doubtful if the following reference to Jupiter is astronomical.

Marcus says:

> "My lord, I aim a mile beyond the Moon;
> Your letter is with Jupiter by this."
> Titus Andronicus, Act IV, Sc. III.

SATURN.—There are four references to this planet, three of which are either mythological or astrological, and one planetary. I will give two quotations, one of each kind:

> "I wonder that thou, being, as thou say'st thou art, born under Saturn, goest about to apply a moral medicine to a mortifying mischief."
> Much Ado About Nothing, Act I, Sc. III.

The following bit of pleasantry shows a happy mixture of love and astronomy:

"*Falstaff.*—Kiss me, Doll.
Prince Henry.—Saturn and Venus in conjunction! What says the almanac to that?" Second Part Henry IV, Act II, Sc. IV.

Some general references to the planets will be given under the subject of astrology. (*To be Continued.*)

THE LIGHT CHANGES of β-LYRAE.

G. W. MYERS.

For Popular Astronomy.

Introductory.

Comformably to the suggestion of Popular Astronomy for November last, that an untechnical presentation of the substance of my recent discussion of the cause of Beta Lyrae's variability would be of interest to its readers, the following sketch of the method used and summary of results are submitted:

It should not be forgotten that whatever subsidiary purposes it may subserve, the vast quantity of observational material on variable stars amassed during the last decade and being augmented daily by the energy and diligence of Chandler, Yendell, Parkhurst, Hartwig, Safarik, Espin and numerous others, together with the light curves based upon it, derives its chief value as a means of revealing the *causes* of stellar light variation. The individual light curves, it is true, are interesting and valuable items of information, in themselves considered, but they do not attain their full measure of value, until they have been considered in connection with their underlying causes. We refuse to be content with a knowledge of what the light fluctuations of a star are, we insist on the inquiry, "why are they so?" After the observer therefore, comes the theorist, and who shall say the work of the one is either more necessary, or more valuable, than that of the other, however much more strongly the achievements of the former may excite the popular enthusiasm? Both have their functions to perform in guessing out the riddle of Nature and either would be shorn of more than half its strength if deprived of the other. The writer would therefore enter his protest against the tendency in certain American quarters to belittle the work of the theorist.

As is well known, the three explanations of stellar variability generally regarded as most plausible, are: (1) The Meteoric Swarm Theory, (2) The Spot Theory and (3) The Satellite Theory.

(1) This theory, which has in recent years been considerably strengthened from its adoption and advocacy by Lockyer, who has brought to its support a great deal of very valuable material from spectroscopic experiments, assumes that the variables are not single masses, but are rather compact swarms of meteorites attended by secondary swarms. Assuming one, or both of the swarms to be self luminous and that the orbit plane of the secondary passes near the earth, there would be a fall of brightness whenever both bodies lie in, or near the sight-line, while at the times of periastron passage of the secondary swarm, the collisions of the outlying meteorites of the two swarms would produce a periodic rise in brightness. Suitable combinations of these two causes will explain a large variety of light fluctuations.

(2) In the second theory, a body whose surface possesses different degrees of brightness rotates about an axis, so as to bring the various parts into view at regular intervals. This cause of variability, combined with a spot periodicity, suffices to explain some sorts of light change.

(3) The Satellite Theory is based on the hypothesis that two bodies revolve around each other in an orbit whose plane passes near enough the earth, so that at inferior and superior conjunctions of the companions, mutual eclipses occur, through which the luminosity of the uneclipsed bodies is reduced. Either, or both of the components may be self-luminous.

There seems to be so much of the purely arbitrary in the underlying hypotheses of theories (1) and (2) as to compel them to yield to the third theory, in cases where the latter is applicable. With proper assumptions regarding the nature, distribution, and periods of the swarms, or spots, any conceivable sort of variation may be explained by theories (1) and (2), but as just suggested, these theories are no advance on their underlying assumptions.

Some months since, it was suggested to me by Professor Seeliger of Munich, that the light curve of Beta Lyrae would be capable of rigorous explanation on some form of the Satellite Theory. I decided to inquire into the matter to some extent, and the discussion which follows was the result of the inquiry. My purpose was to treat the photometric estimates wholly apart from the spectroscopic and to ascertain what each class of observations was capable of yielding and finally to compare the results. Whether or not the inquiry was in any measure successful, the reader will of course, judge for himself.

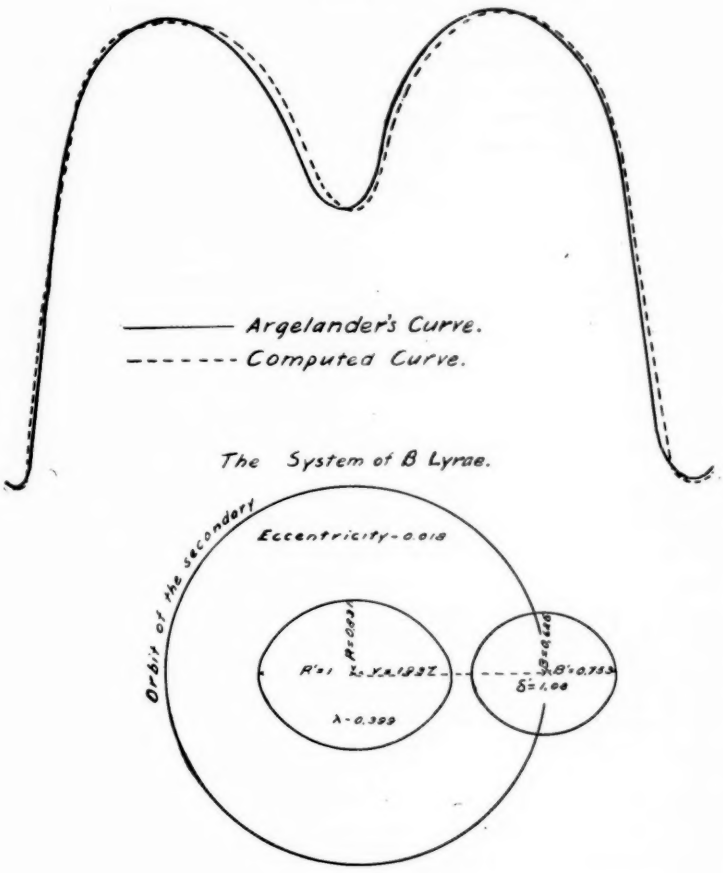
Historical.

The variability of Beta Lyrae was discovered by Goodericke in 1784, but nothing of importance was done in the study of the light changes of the star, aside from the confirmation of their periodic nature and of the existence of two unequal minima, until Argelander developed his classical method of studying the light fluctuations of such stars. Applying his own method to the study of Beta Lyræ, he obtained and published his first light curve of this star in 1842, a second in 1844 and a third in 1859. The last was based on 1500 careful photometric estimates extending over 19 years. With a view to ascertaining whether his observations contained systematic errors, he divided his observations into three series and drew a curve for each series. The deviations of these curves were so slight as to justify their being regarded as purely accidental, so that he combined them all into a single mean curve. The light curves of this star constructed by Oudemans and by Schoenfeld were reviewed, but were found to present no material deviations from Argelander's third curve. This latter curve was therefore taken as a basis for study, since the slight discrepancies of the curves relating to this early epoch could not exert an appreciable influence on the discussion. Later curves of this star have been constructed by Schur, Lindemann and very recently by Professor Pickering. These curves however, refer to a very much later epoch and should be discussed apart from the earlier curves. Some considerations based on Lindemann's curve constructed from Plassmann's observations, are appended in the closing paragraph of the discussion. The writer has not yet had an opportunity to become sufficiently familiar with Pickering's work to warrant any statement with regard to it. It relates also to a recent epoch.

Nature of Light Variation.

This star is the best example of Pickering's fourth class. Its curve consists of two nearly equal maxima of the 3.4 magnitude and of a primary minimum of the 4.5 magnitude and secondary minimum of 3.9 magnitude. Or, in the language of Argelander's grades, the curve starting at a brightness of 3.34 grades, rises in about 3 days to a brightness of 12.33 grades, falls after three more days to a brightness of 8.53 grades, rises during the same interval to the former brightness of 12.33 grades to fall, at last, after the same time, to the initial brightness. This process is then indefinitely repeated. The curve drawn in full line in the upper part of the adjoining plate is Argelander's 3rd curve showing these changes.

PLATE 1.

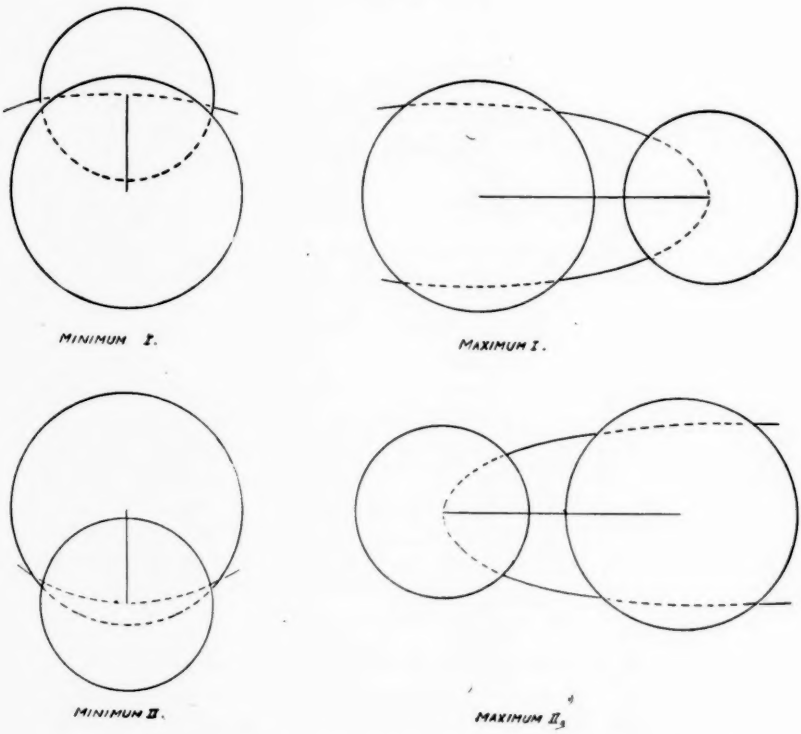


Hypothesis.

It is assumed that the light variation is produced by two revolving, self-lumious bodies, which stand beside each other at the instants of the maxima, neither disc obscuring any portion of the other; while at the times of the minima, the discs overlap to a greater or less extent. The lower minimum is produced by the passage of the darker body in front of the brighter, and the higher, or secondary, minimum by the obscuration of the darker by the brighter body. The figures of Plate II show the relative

positions of the bodies at the chief epochs of variability. That the two components are unequally bright is shown by the fact that at the primary minimum, the star's light is reduced by 66%, and at the secondary minimum by only 36% of the mean brightness at the maxima, unless the orbital eccentricity is a very considerable magnitude. In the sequel, it is shown however, that the eccentricity must be quite small.

PLATE 2.



Whether one or both of the bodies be replaced by a more or less nearly spheroidal swarm would, in no essential particular, modify the conclusions of this discussion. But for the sake of simplicity merely, the components are both assumed to be self-luminous solids, each disc shining with uniform brightness.

A number of spectroscopic observations of this star have been recently made and a little space has been devoted to a discussion

of some of the results of the best of them available to me. The most complete series of spectroscopic observations of β Lyrae known to the writer, at the time of this discussion, was that of A. Belopolsky, made between the 24th of August and the 26th of November 1892 and published in detail in *Melange math. et ast. t. VII.* They were made under extraordinarily favorable circumstances and I have therefore, not hesitated to base some inferences upon them. A very recent article by Belopolsky in the Ap. J. containing his recent work seems to confirm the validity of his earlier work.

Besides Belopolsky, Professors Pickering, Vogel, Keeler and Lockyer and Father Sidgreaves have engaged in the spectroscopic study of this star and have enriched our knowledge of it by much valuable material and many fruitful suggestions.

§ 1. The Orbital Eccentricity of β Lyrae.

Assuming that Argelander's curve may be explained by means of two separate and distinct revolving bodies, it is at once evident,

(1) That one or both of the bodies must be appreciably flattened; for, were this not so, the light curve would run horizontally, so long as the luminous discs of the bodies stand wholly off each other. This is at once apparent, when we reflect that the luminous intensity of a sphere is solely a function of the area of the luminous surface and that so long as the discs are separate, this surface is the sum of two discs and therefore constant, since the discs are circular. But, since the curve indicates no appreciable duration of the maxima, the bodies must be flattened, or they must be in contact with each other. Both circumstances may of course simultaneously prevail.

(2) That the eccentricity of the orbit must be very small. This appears directly both from the approximate equality of duration of the eclipses at the times of the minima and also from the small differences of the four chief intervals:

Min. I — Max. I = 3.125 days
Max. I — Min. II = 3.250 "
Min. II — Max. II = 3.167 "
Max. II — Min. I = 3.368 "

But the eccentricity of the orbit may be shown mathematically to be small. Assuming the primary minimum to occur when the darker component is at interior conjunction and that in this position, the mean and true anomalies are denoted by M and v respectively, it is readily seen that the values of v at Max. I, Min. II, Max. II may be denoted by $v + 90°$, $v + 180°$ and $v + 270°$

respectively. Assuming further that the Newtonian law holds in the system and that the second and higher powers of the eccentricity are negligible, the well known relation between v and M may be written $v = M + 2e \sin M$,
and satisfying this equation for the chief epochs, we have, (*v.* Fig. 1),

$$\begin{aligned} v_1 &= M_1 + 2e \sin M_1, \\ v_1 + 90^\circ &= M_2 + 2e \sin M_2, \\ v_1 + 180 &= M_3 \quad 2e \sin M_3, \\ v_1 + 270 &= M_4 + 2e \sin M_4, \end{aligned}$$

where the subscripts refer to the chief epochs in order from Min. I to Max. I, to Min. II, etc. Solving these equations by combining the sets of three into single pairs and using $\mu = 2\pi/P$, where $P = 12.91$ days, from each pair used there resulted a set of independent values for v_1, e and M_1. The mean anomalies M_1, M_2, M_3, M_4 are connected by means of the chief intervals enumerated above. Only one of them has to be computed from the equations (vide, upper part of Pl. 3). The two sets of resulting values are:

$$\begin{aligned} v_1 &= -\ 31^\circ\ 33'. \quad e = 0.0186. \quad M_1 = -\ 30^\circ\ 28'.0 \\ v_1 &= \ \ 209\ \ 25\ . \quad e = 0.0196. \quad M_1 = \ \ 209\ \ 32\ .4 \end{aligned}$$

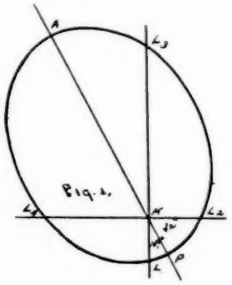
The first set requires a shift of Max. II by $4^h.06$, while they rigorously satisfy the other three chief epochs and the second set satisfy Min. I, Min. II and Max. II, but require a backward displacement of Max. I by 4 hours. The close agreement of the two values of e indicates that the value is not far from 0.02, which is small enough to justify neglecting higher powers. So slight a difference in the chief intervals producing so great a change in v_1 and M_1 emphasizes the same inference.

After an approximate value of the common ratio (q) of the semi-axes of the assumed ellipsoids has been found, a minor limit for the eclipse at Min. I and thence, a major limit for the distance between centres of the companions may be found. It develops that the greatest possible value for this distance is 2.4 times the semi-major axis of the larger ellipsoid. This may be readily shown as follows:

Assume the bodies to be spheres of radii equal to the respective semi-minor axes of the ellipsoids and let κ denote the radius of the smaller sphere in terms of that of the larger.

Also let r denote the radius of the real orbit, assumed circular, and x, half the distance between the nearest points of the spaces occupied by the secondary at the beginning and final instants of the eclipse at Min. I.

PLATE 3.



KEPLER'S LAW

$v = M + 2e \sin M + \frac{5}{4} e^2 \sin 2M$ etc.

LENGTHS OF INTERVALS

Min I – Max I = 3.123 days
Max I – Min II = 3.250 "
Min II – Max II = 3.169 "
Max II – Min I = 3.368 "

$v = M + 2e \sin M$

(1) $v_1 = M_1 + 2e \sin M_1$
(2) $v_2 = M_2 + 2e \sin M_2$
(3) $v_3 = M_3 + 2e \sin M_3$
(4) $v_4 = M_4 + 2e \sin M_4$

$v_2 - v_1 = \frac{\pi}{2}$
$v_3 - v_1 = \pi$
$v_4 - v_1 = \frac{3}{2}\pi$

(5) $\frac{\pi}{2} = 2m_1 + 4e \cos(M_1 + m_1) \sin m_1$, where $2m_1 = M_2 - M_1 = 3.125\ \mu = 87° 8'.4$
(6) $\pi = 2m_2 + 4e \cos(M_1 + m_2) \sin m_2$, $2m_2 = M_3 - M_1 = 6.375\ \mu = 177° 46'.2$
(7) $\frac{3\pi}{2} = 2m_3 + 4e \cos(M_1 + m_3) \sin m_3$, $2m_3 = M_4 - M_1 = 9.542\ \mu = 266° 4'.8$

From (5) and (6), $\mu = \frac{2\pi}{P}$ and $P = 1.291$ days

(b) $M_1 = -30° 28'$, $v_1 = -31° 33'$
$e = 0.0186$
$v_4 = 270° + v_1$, $M_4 = 240° 19'$

This requires Min. I to be about 31h.3 before periastron.

From (5) and (7)

(c) $M_1 = -209° 32'.4$
$e = 0.0196$
$v_1 = +209° 25'$

(b) requires a backward displacement of Max 2 of Argelander's curve by about 4 hours and (c) requires the same displacement of Max I.

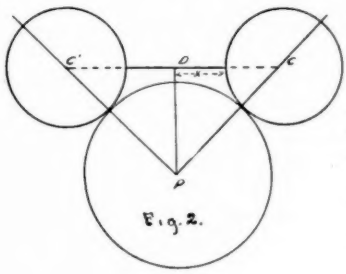


Fig. 2.

R = the radius of the smaller component.
r = " " " " real orbit.
x = half the distance between the nearest points of the positions of its companion at the beginning and end of the eclipse.

Then

$CPC' \geqq 3.167 \times 27°.887 = 88° 20'$

consequently

$CPD \geqq 44° 10'$

Also $r \leqq (x + R) \csc 44° 10' \leqq 1.435 (x + R)$

$x \leqq 1$ and $R \leqq 1$

hence $r \leqq 2.87$

Then (v. Fig. 2, Pl. 3)

$$CPC' \geqq 3.167 \times 27°.887 = 88° 20'.$$

Consequently,

$$CPD \geqq 44° 10'.$$

Also

$$r \leqq (x + \varkappa) \csc 44° 10'$$
$$\leqq 1.435\ (x + \varkappa).$$

But

$$x \leqq 1 \text{ and } \varkappa \leqq 1,$$

hence $r \leqq 2.87$ times the semi-minor axis of the larger ellipsoid, or 2.4 times its semi-major axis, since $q = \frac{R'}{R}$ is later found to be 1.2.

A little consideration will show that if the bodies be assumed flattened the eclipse duration must be lengthened and the distance of centres correspondingly shortened. With so small a distance between the components, the orbital eccentricity must be small, otherwise the bodies must interpenetrate and coalesce at periastron passage.

§ 2. Flattening.

It is assumed, (1) that the masses are separated, (2) that the bodies are deformed into ellipsoids of revolution by mutual tidal effects, and (3) that the periods of rotation and of revolution are equal to 12.91 days. (Librations excepted).

Taking the centre of the large ellipsoid as origin of coordinates, the line of sight as the x-axis and the tangent plane to the celestial sphere at the origin as the yz-plane, the equation of the light curve, after some transformations and reductions, is found to be,

$$L = \frac{1}{1 + \varkappa^2 \lambda}\left(\frac{1}{\sqrt{\sin^2 \varphi + \left(\frac{R}{R'}\right)^2 \cos^2 \varphi}} + \frac{\lambda \varkappa^2}{\sqrt{\sin^2 \varphi + \left(\frac{B}{B'}\right)^2 \cos^2 \varphi}}\right)$$

where the signification of the symbols is as follows:

L denotes the ratio of the aggregate luminous intensity of both instantaneous elliptical discs, to its value when both ellipsoids are seen "end on" *i. e.* when the combined intensity of brightness is least,

λ, the ratio of the brightness of the bodies,

$\varkappa$, the ratio $\frac{B'}{R'}$

B, R, B' and R' denotes the semi-minor and semi-major axes respectively, of the smaller and larger ellipsoids, B referring to the smaller and R to the larger, and φ is the angular distance of the

secondary body from the node and is equal to $\frac{2\pi t}{24P}$, P, being the period and t the time in hours counted from node-passage.

In the formula above, it was assumed as a first approximation that the two ellipsoids are equally flattened, or that they are similar ellipsoids of revolution. Such forms being figures of equilibrium, this assumption is allowable. From the unsymmetrical character of the residuals computed later, it was seen that no modification of this hypotheses could improve their character so long as a symmetrical deformation is assumed.

Placing $q = \frac{R'}{R} = \frac{B'}{B}$ the foregoing equation becomes

$$L = \frac{1}{\sqrt{\sin^2 \varphi + \frac{1}{q^2} \cos^2 \varphi}}.$$

This equation applies so long as neither disc occults any portion of the other.

§ 3. Equations for the Brightness During Occultations.

Equations were then derived whereby the ratio of the aggregate instantaneous brightness of both discs to the aggregate brightness when the discs were of maximum size. These developments were somewhat tedious and need not be given here. The problem to be solved was to pass two ellipses of varying major axes over each other and to compute the ratio of the sum of the unocculted portions to the maximum value of this sum for various instants of time, the law of motion being assumed. It was however, a mere problem of geometry of space and its solution will be suggested by Fig. 3 of Pl. 4.

Suffice it to say that in all, three equations were obtained by means of which the instantaneous light ratios of the system could be computed from the orbital elements and known values of $\varkappa$, λ and q, and conversely. The first of these equations was applicable when neither ellipsoid suffered occultation by the other, the second, while the brighter disc was undergoing occultation and the last, while the fainter was totally, or partially occulted. All these equations in the first analysis were based on the hypothesis of a circular orbit.

§ 4. Equations for Elliptical Motion.

Differential equations were then derived for correcting the circular orbit into an ellipse of small eccentricity. The system of equations (I), (II), (III), (IV) and (V) were obtained, (I) and (II) apply ing to circular and (III), (IV) and (V) to elliptical motion.

PLATE 4.

NOTATION AND EQUATIONS

$OA = R_1$; $OA' = R$; $O'A' = \beta_1$; $CO' = a$

$AOE = \Phi$; $A'O'E = \Phi'$; $\pi - \Phi$ and $OO' = P$

J_1' and J_2' the ratios of the instantaneous brightnesses at Min I and Min II respectively to the sum of the brightnesses due to both instantaneous discs shining full phase.

J_1 and J_2, the same ratios with respect to the sum of the brightnesses when the discs are greatest.

We readily obtain

$J_1' = 1 - \frac{1}{\pi(1+\kappa^2\lambda)}\{\Phi + \kappa^2\lambda(\pi - \Phi) - P'\sin\Phi\}$

For brevity, put

$M_2 = \{1+\kappa^2\lambda\}\pi(1 - J_1')$

Then

(3) $M_2 = \Phi + \kappa^2\Phi' - P'\sin\Phi$

or $M_2 = \Phi + \kappa^2\Phi' - \kappa\sin(\Phi' - \Phi)$

Since $P = \frac{a}{R_1} = \frac{\sin(\Phi' - \Phi)}{\sin\Phi}$

according as

$\Phi' < 90°$ or $\Phi' > 90°$

and

$\cos\Phi = \frac{r^2 + a^2 - R^2}{2ar}$

$\sin\Phi = k\sin\Phi'$

It is better to use (3) for $\Phi' < \frac{\pi}{2}$ only, and for $\Phi' > \frac{\pi}{2}$, to use

$M_2 = \kappa^2\pi - \pi(1+\kappa^2\lambda)(1 - J_1')$

consequently

$M_2 = \kappa^2\Phi' - \Phi - P'\sin\Phi$

or

$M_2 = \kappa^2\Phi' - \Phi + \kappa\sin(\Phi' - \Phi)$

where

$P' = \frac{\sin(\Phi' - \Phi)}{\sin\Phi}$

The above hold for Min I only.

For Min 2 we obtain similarly

$J_2 = 1 - \frac{\lambda}{\pi(1+\kappa^2\lambda)}\{\Phi + \kappa^2(\pi - \Phi) - P'\sin\Phi\}$

$M_2 = \pi\frac{1+\kappa^2\lambda}{\lambda}(1 - J_2')$

$M_2 = \Phi + \kappa^2\Phi' - P'\sin\Phi$

$M_2 = \kappa^2\pi - \pi\frac{(1+\kappa^2\lambda)}{\lambda}(1 - J_2')$

$M_2 = \kappa^2\Phi' - \Phi + P'\sin\Phi$

All the remaining formulæ hold for both minima

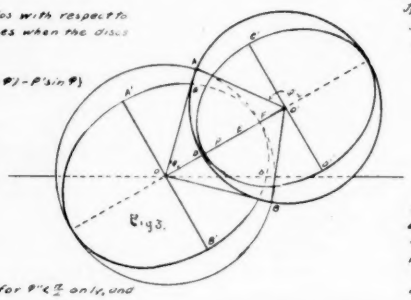


Fig 3.

λ = ratio of brightnesses of discs

π = " " the semi-axes

$\pi = 3.1416$

$q = \frac{R}{R'} = \frac{\beta_1'}{\beta_1}$

β = longitude of companion in its orbit.

L_1 = the sum of the brightnesses of both momentary ellipses.

L_m = the maximum of L_1

L_2 = the instantaneous duringeach minimum

i = inclination.

Call

$f = \frac{\pi R_1 \rho}{\pi R_1 R} = \frac{\beta_1'}{R} = \frac{\beta_1'}{a} = \frac{1}{\sin i\sqrt{q^2\cos^2\beta + \sin^2\beta}}$

$\frac{L_1}{L_m} = \frac{\pi\beta_1' R + \pi\lambda\beta_1 a}{\pi R(1+\kappa\lambda)a} = \frac{\beta_1'}{R} = f$

$J_1 = \frac{L_1}{L_m} = \frac{L_1}{L_2} \times \frac{L_2}{L_m} = f\frac{L_2}{L_1}$

$J_1' = \frac{L_2'}{L_1'}$

consequently

$J_1 = f J_1'$

similarly

$J_2 = f J_2'$

also

$P' = \frac{a}{R_1'} = \frac{a}{f}$

N.B. Since i is found later to be nearly $\frac{\pi}{2}$ we assume this in the equations of the last column

Assuming the orbit circular, we have if r and ρ denote the true and apparent radii vectores, and $\Phi = \frac{\pi}{2}$ and α the longitudes in the true and apparent orbits respectfully

$P\cos\alpha = r\sin\theta$

$r\sin\alpha = r\cos i\cos\theta$

consequently

$\rho^2 = r^2\sin^2\theta + r^2\cos^2 i\cos^2\theta$

Differentiating former equations and reducing we find

$\delta\Phi = \frac{\delta M_2}{2\pi f q\Phi'}\sin(\Phi' - \Phi)$

$\delta\Phi = \frac{\delta M_2}{2\pi f q\Phi'}\sin(\Phi' - \Phi)$

and if $\kappa > 1$

$\delta\Phi = \frac{\delta M_2}{2\pi f q\Phi'}\sin(\Phi - \Phi')$

(I). $$\pi(\lambda + \kappa^2)\,\delta J_1 = 2\kappa K_1\,\delta\kappa + \frac{2\rho\sin\varphi'}{r}\,\delta r + \frac{r^2\cos^2\beta\sin\varphi'}{\rho}\,\delta(i'^2)$$

where $K_1 = AJ_1 f^2\cos^2\beta + B(f - J_1) - f\varphi - C\rho f^2\cos^2\beta\sin\varphi'$,

$A = \kappa q\lambda$, $B = \kappa\left(1 + \frac{\lambda(1-\lambda)}{\kappa^2}\right)$, and $C = \frac{2q^3}{m}$

(II). $$\frac{\pi(\lambda + \kappa^2)}{\lambda}\,\delta J_1 = 2\kappa K_{II}\delta\kappa + \frac{2\rho\sin\varphi'}{r}\delta r + \frac{r^2\cos^2\beta\sin\varphi'}{\rho}\,\delta(i'^2)$$

where $K_{II} = \frac{AJ_{II} f^2\cos^2\beta}{\lambda} + \pi(f - J_{II}) - C\rho f^2\cos^2\beta\sin\varphi'$,

and $i' = \frac{\pi}{2} - i$

(III). $$\pi(\lambda + \kappa^2)\,\delta J_1 = 2\kappa K_1\,\delta\kappa + N_1\sin\beta\,\delta x - N_1\cos\beta\,\delta y + \frac{2\rho\sin\varphi'\,\delta r}{r} + \frac{r^2}{\rho}\cos^2\beta\sin\varphi'\,\delta(i'^2),$$

where $K_I = AJ_I f^2 \cos^2\beta + B(t - J_I) - f\varphi - C\rho f^2 \cos^2\beta \sin\varphi'$

$$L_I = \left\{ \rho \sin\varphi' - \frac{\pi}{2}(\lambda + \varkappa^2) \right\} f^2 (1 - q^2) \sin 2\beta$$

$$N_I = L_I + \frac{r^2}{\rho} \sin\varphi' \sin 2\beta$$

(IV). $$\pi \left(\frac{\lambda + \varkappa^2}{\lambda}\right) \delta J_{II} = 2\varkappa K_{II} \delta\varkappa + N_{II} \sin\beta\delta x - N_{II} \cos\beta\delta y + \frac{2\rho}{r} \sin\varphi' \delta r + \frac{r^2}{\rho} \cos^2\beta \sin\varphi' \delta(i'^2),$$

where $K_{II} = \frac{AJ_{II} f^2 \cos^2\beta}{\lambda} + \pi(t - J_{II}) - f\varphi - C\rho f^2 \beta \sin\varphi'$

$$L_{II} = \left\{ \rho \sin\varphi' - \frac{\pi}{2} \frac{\lambda + \varkappa^2}{\lambda} \right\} f^2 (1 - q^2) \sin 2\beta$$

$$N_{II} = L_{II} + \frac{r^2}{\rho} \sin\varphi' \sin 2\beta$$

(V). $$\frac{\delta J}{f^3 \cos\beta} = 2\frac{q^3 \varkappa\delta\varkappa}{m} - (1 - q^2) \sin^2\beta\delta x + \frac{(1 - q^2)}{2} \sin 2\beta\delta y.$$

The subscripts I and II refer to Min. I and Min. II.

It was now possible to scale off the instantaneous brightness of the star from Argelander's curve, convert it into the equivalent light ratio and substitute in the equations, from which provisional orbital elements were obtained. These provisional elements were corrected by forming 48 observation equations for as many points uniformly distributed along the light curve and determining the correction to the elements by least squares.

The provisional values of λ, $\varkappa$ and q were obtained thus; For the chief epochs, we have,

(1) $$\frac{1 + \varkappa^2\lambda - \alpha\varkappa^2\lambda}{1 - \alpha\varkappa^2 + \varkappa^2\lambda} = 1.8536 = \frac{\text{Brightness at Min. II}}{\text{Brightness at Min. I}}$$

(2) q. $$\frac{1 + \varkappa^2\lambda}{1 - \alpha\varkappa^2 + \varkappa^2\lambda} = 2.9123 = \frac{\text{Brightness at Max.}}{\text{Brightness at Min. I}},$$

and α is the area of the overlapping portions of the discs at the times of the minima on the hypothesis for circular orbit. For brevity put $c = 1.8436$ and $m = 2.9123$.

(1) and (2) give

(3) $$\frac{\alpha\varkappa^2\lambda}{1 + \varkappa^2\lambda} = \frac{m - cq}{m}$$ and (4) $$\frac{\alpha\varkappa^2}{1 + \varkappa^2\lambda} = \frac{m - q}{m}.$$

whence (5) $$\lambda = \frac{m - cq}{m - q}.$$

From (3) and (1) we have

(6) $\frac{1}{\varkappa^2} = \frac{m}{m-q}\alpha - \frac{m-cq}{m-q}$, and from (4)

$$m - q = m\frac{\alpha\varkappa^2}{1+\varkappa^2\lambda}.$$

But since $\alpha\varkappa^2$ and $1 + \varkappa^2\lambda$ are positive magnitudes (being quantities of light), "m" must be larger than q, $\frac{1}{\varkappa}$ and α must then increase and decrease together and will reach their maximum and minimum values together.

If now

$\varkappa^2 \leqq 1$, then $\alpha \leqq 1$ and from (6) it follows that $\frac{1}{\varkappa^2} < \frac{cq}{m-q}$, or $\varkappa^2 \geqq \frac{m-q}{cq}$. But from the meaning of α, it is apparent that if

$$\varkappa^2 \geqq 1,\ \alpha \geqq \frac{1}{\varkappa^2} \text{ and from (6)}$$

$$\frac{1}{\varkappa^2} < \frac{m}{m-q}\frac{1}{\varkappa^2} - \frac{m-cq}{m-q}, \text{ consequently, } \varkappa^2 < \frac{q}{m-cq}.$$

Both cases may be comprised in the inequality

(7) $$\frac{m-q}{cq} \leqq \varkappa^2 > \frac{q}{m-cq}.$$

From (7) we may write

$$\frac{m-q}{cq} < \frac{q}{m-cq}, \qquad \text{whence} \qquad q > \frac{m}{c+1}.$$

Substituting the values of m and c, given above we find

$$q\left(=\frac{K'}{R}=\frac{B'}{B}\right) > 1.0205,$$

hence it appears that *there must be a flattening of the discs.*

A few transformations similar to those just given make it apparent that the smaller of the limits within which $\varkappa^2$ must lie decreases and the larger increases, when q is increased so that to be very certain to include all possible values of $\varkappa^2$, a value somewhat larger than the most approximate value of q was used.

This approximate value of q was obtained by computing light curves from the equation

$$L = \frac{1}{\sqrt{\sin^2\varphi + \frac{1}{q^2}\cos^2\varphi}}$$

given above, for a large number of assumed values of q. Since this equation applies only while the discs are wholly off each

other, it merely includes the effect due solely to the ellipsoidal form of the bodies. If the effect of deformation be computed then, and deducted from Argelander's curve on either side of the maxima, a curve would remain, (provided the proper value of q be used,) which would be due wholly to two revolving spheres. Such a curve must run horizontal while the discs are off each other. Ten assumed values of q were used and 1.2 gave for the six points before and after the maxima the value of the respective ordinates 10.33, 10.55, 10.76, 10 78, 10.78, 10.79, 10.79, 10.78, 10.78, 10.76, 10.55 and 10.33. These are sufficiently nearly equal to justify the assumption that $q = 1.2$ is a close approximation to the correct value. In the location of the limits for $\varkappa^2$ by the method above outlined q was taken larger than this so as to be sure to get the limits for $\varkappa^2$ wide enough. The value used for this purpose was 1,275. This gave

$$0.6928 \leqq \varkappa^2 \leqq 2.3228 \text{ from (7), or}$$

$$0.8323 \leqq \varkappa \leqq 1.5241.$$ It was then necessary to investigate only the values of $\varkappa$ lying between these limits. The values, 0.8323, 0.9049, 1.0000, 1.2883 and 1.5241 were chosen and by means of suitable equations, 7 independent values of the radius rector of the orbit were computed for each of these values of $\varkappa$. The correct value would of course, give nearly equal values for r, if the orbit is approximately circular. The last value, $\varkappa = 1.5241$, gave the best values for r, and it was selected as the approximation to $\varkappa$. Satisfactory values could not be obtained however, on any assumption for the orbital inclination i, other than $i = 90^\circ = \frac{\pi}{2}$. The weighted mean of the 7 values of r computed from $\varkappa = 1.5241$ and $i = \frac{\pi}{2}$, was $r = 1.8344$.

These values of λ, $\varkappa$, q, r and i were used to compute the coefficients of the differential equations for correcting the circular elements by least squares and the corrected values were used for the coefficients of the differential equations for passing from the circular to the elliptical elements.

48 of these differential equations gave for the best elliptical elements the following values and ratios:

$a = 1.9366$	$P = 12.91$
$e = 0.0176$	$\mu = 27^c.887$
$i = 90^\circ$	$\varkappa = 0.7528$
$\eta = 94^\circ 53'$ from node	$\lambda = 0.3990$
$\Omega = 0$ (assumed)	$q = 1.2031$
$T = 1885, 13^d\ 6^h.35$	

For convenience in solving some of the equations, it was better to use the radius of the large body as unity and this required that the reciprocal of 1.5241 should be used for $\varkappa$. The necessary alterations in the equation were then made to suit this value of $\varkappa$.

A light curve was then computed with these elements and it is shown in Plate I, drawn in a dotted line over Argelander's curve. The results of computation are also tabulated in Plate 5.

PLATE 5.

DEFINITIVE ELEMENTS.

$a = 1.9366$ $\quad p = 12.91$

$e = 0.0176$ $\quad \mu = 27.887$

$i = 90°$ $\quad \varkappa = 0.7528$

$\eta = 94°53'$ from node $\quad \lambda = 0.3990$

$\Omega = 0$ (assumed) $\quad q = 1.2031$

$\tau = 6^d 15^h 4$ after Min I or

$T = 1833$ Jan. $13^d\ 6^h 35$

$M = \mu(t-\tau)$, $\quad V = M + 2e \sin M$,

$r = \frac{a(1-e^2)}{1+e\cos v}$, $\quad \rho = r\frac{\cos\beta}{\cos(p-\Omega)}$, $\quad tg(p-\Omega) = -\cos i \operatorname{ctg}\beta$

t	Minimum I.			Minimum II.		
	J_B	J_R	δJ_{B-R}	J_B	J_R	δJ_{B-R}
−72	0.9963	0.9956	+0.0007	0.9918	0.9970	−0.0052
−66	0.9870	0.9852	+0.0018	0.9836	0.9945	−0.0109
−60	0.9683	0.9701	−0.0018	0.9696	0.9833	−0.0137
−54	0.9524	0.9513	+0.0011	0.9490	0.9672	−0.0182
−48	0.9147	0.9270	−0.0123	0.9258	0.9482	−0.0224
−42	0.8732	0.8849	−0.0117	0.8995	0.9217	−0.0222
−36	0.8209	0.8268	−0.0059	0.8680	0.8886	−0.0206
−30	0.7296	0.7525	−0.0229	0.8306	0.8494	−0.0188
−24	0.5836	0.6019	−0.0183	0.7836	0.8048	−0.0212
−18	0.4336	0.4993	−0.0657	0.7246	0.7558	−0.0312
−12	0.3661	0.4275	−0.0614	0.6674	0.7044	−0.0370
−6	0.3484	0.3487	−0.0003	0.6433	0.6542	−0.0109
0	0.3433	0.3433	± 0	0.6363	0.6368	−0.0003
+6	0.3499	0.3488	+0.0011	0.6472	0.6372	+0.0100
+12	0.3988	0.4275	−0.0287	0.6762	0.6689	+0.0073
+18	0.5306	0.5591	−0.0285	0.7340	0.7203	+0.0137
+24	0.6572	0.6624	+0.0052	0.7978	0.7716	+0.0262
+30	0.7644	0.7528	+0.0116	0.8498	0.8289	+0.0209
+36	0.8416	0.8266	+0.0150	0.8931	0.8622	+0.0309
+42	0.8857	0.8845	+0.0012	0.9255	0.8997	+0.0258
+48	0.9234	0.9268	−0.0034	0.9524	0.9307	+0.0217
+54	0.9537	0.9508	+0.0029	0.9627	0.9545	+0.0082
+60	0.9732	0.9694	+0.0038	0.9881	0.9732	+0.0149
+66	0.9870	0.9847	+0.0023	0.9977	0.9877	+0.0100
+72	0.9940	0.9952	−0.0012	1.0049	0.9970	+0.0079

Discussion of Systematic Differences of the Curves.

The systematic deviation of the computed from the observed curve before and after Min. II, may be very readily explained by the fact that deformations of the discs, disturbances due to intensified tidal effects etc., are very probably produced at the time when the secondary rounds periastron. The inertia of the material of both bodies might delay the instant at which these effects would have greatest influence on the brightness, so that the observed curve would necessarily lie above the mean computed curve for a while after Min. II, (Min. II lies near periastron). The first effect of the mutual reactions would be to elongate the ellipsoids which, at the secondary minimum, are viewed "end on," and hence, the apparent discs would be seen to contract for a time. If it be imagined, that this contraction gets the advantage for a short time, of the increased luminosity due to deep seated disturbances of its masses at periastron passage, the drop in the observed below the computed curve before Min. II is satisfactorily explained. Excepting for a short time just before Min. I the two curves show sufficient accordance. The most uncertain portion of the entire curve based on observations would probably be just here. So that we may at least claim that the curve of Argelander is explained thoroughly satisfactorily by the satellite theory of the star's variability.

§ 4. Spectroscopic Considerations.

From 13 carefully executed spectrogramms made by Belopolsky between Sept. 23 and Nov. 26, 1892, the following orbital elements were computed by the method of Rambaut given in *Mon. Not.* Vol. 51, p 316:

V (= the velocity of the centre of gravity of the system relative to the Sun) equals — 0.8 kilometers.
$T = 26.93$ Sept. 1892.
$e = 0.107$
$\tilde{\omega} = -79° 17'$ from node.
$a \sin i = 15836000$ kilometers.
$P = 12\ 91$ days.

Putting $\sin i = 1$ as seems to be indicated from the photometric estimates, a equals 15836000 kilos. This is, of course, the mean distance of the *absolute* orbit of the component which gave the *absolute* displacements of Belopolsky's *F*-line.

In "Ast. and Astrophys." 1894 p. 577, Lockyer gives the following *relative* velocities obtained from a photograph taken Aug. 24.46, 1893:

$H_\gamma = 155.0$ miles
$H_\delta = 154.0$ "
$\lambda_{4025} = 158.0$ "

The mean of these is 155.7 miles = 250.5 kilometers. Correcting this for the Earth's motion for the date, it becomes 259.8 miles. From the velocity curve used with Belopolsky's observations, the absolute velocity for this same epoch is 82.0 kilometers. The ratio of relative to absolute velocities is then 3,168 and of course, this is the ratio of the corresponding dimensions of the relative and absolute orbits. Consequently the mean distance of the relative orbit is $A = 50175000$ kilometers.

But from the well known relation, $\frac{a}{A} = \frac{m}{M+m}$, there results, $\frac{m}{M} = \frac{1}{2.168}$, where m and M denote the masses of the smaller and larger components respectively.

We have also, if δ' denote the ratio of the density of the brighter to that of the darker body,

$$\frac{A}{a} = \frac{M+m}{M} = 1 + \delta' \varkappa^3, \text{ or } \frac{A}{a} = \frac{M+m}{M} = 1 + \frac{1}{\delta' \varkappa^3}$$

and the first, or second of these equations is to be used according as Belopolsky's F-line were produced by the smaller, or larger mass.

Computing the sum of the masses from $M + m = \frac{A^3}{P^2}$, and using the values of A, P, $\varkappa$ and A/a given above,

$$\delta' = 5.083 \text{ or } \delta' = 1.081.$$

This furnishes a means of deciding which gave the F-line, for it is hardly probable that two masses of so nearly the same size and so near together as is the case here, could differ so greatly in density that one should be 5 times that of the other and we infer therefore, that Belopolsky's F-line was produced by the larger component. This of course, might readily be the case, if we imagine the substance producing the F-line to be distributed throughout the atmosphere of the larger body in much greater quantity than it is in the atmospheric envelope of the smaller. The greater gravitational force of the large body would necessarily have such a tendency.

From the equations above

$$\begin{aligned} M + m &= 30.56 \text{ solar masses} \\ M &= 20.01 \quad " \quad " \\ m &= 9.65 \quad " \quad " \end{aligned}$$

From $$\frac{M}{S} = \delta_1 \frac{R'R^2}{H^3} = \frac{\delta_1}{q^2}\left(\frac{R'}{H}\right)^3,$$

where S is the Sun's mass, H, its radius, δ_1 is the density of the larger body in terms of solar density and M, R', R and q have their former significance, we have

$$\delta_1 = \left(\frac{M}{s}\right) q^2 \left(\frac{H}{R'}\right)$$

and since $R' = \frac{A}{1.9366} = 25908000$, from the foregoing data,

$$\delta_1 = 0.00058.$$

Calling δ_2 the density of the smaller body in the same unit as is used with δ_1, the result

$\delta_2 = \delta' \delta_1 = 0.00063$, or *the mean density of the system is about 0.0006, which is comparable to nebular density*, being somewhat less than atmospheric density. This fact, coupled with the extreme nearness of the components, makes it highly probable that in β Lyrae, we have the first concrete example thus far known to science, of a world in the "process of making."

It is proper to say that the residuals in the least square solution are not very greatly increased by a diminution of the distance of centres from the most probable value 1.9366, to 1.8, which would require the bodies to touch. There can be no doubt whatever, that the two bodies are closer together compared to their dimensions, than is the case with any other system thus far known. It is certain that if the bodies are separated at all, they are perilously near each other and we may even have in β Lyrae's "System," for it now deserves that name, one of Poincare's classical figures of equilibrium. In any case, the system is and for many years will continue to be one of the most interesting in all the heavens.

A few words explanatory of the result that the smaller companion is the brighter and I close. Spectroscopists disagree greatly as to the detail to be seen in the spectrum of this star, but all agree that the bands characteristic of a dense absorbing atmosphere are present. There is also general agreement that the absorption spectrum is most distinct at the time of Min. I and that the continuous spectrum is most marked at Min. II. With two bodies so near together as these, a single atmosphere would envelop both bodies. The mechanical theory of gases tells us such an atmosphere would arrange itself in equipotential surfaces, whose centre would concide with the centre of gravity of the combined mass. Those surfaces which lie down close to the body would conform more or less closely to the accidential irre-

gularities of surface of the compound body, but the more elevated ones would become more nearly spherical. At no great distance from the surface of the body they would not greatly differ from exact sphericity. If the density of the larger body should be much greater in its remote, than in the nearer hemisphere, these surfaces would pass close around the remote end of the small body, some even striking the mass and allow this end to protrude far into the atmosphere and thus the spectral pecularities mentioned above find a simple and rational explanation. It does violence, in no way to the fact that secondaries should be denser and darker than their primaries. The facts are graphically represented in Fig. 4 of Plate 6.

PLATE 6.

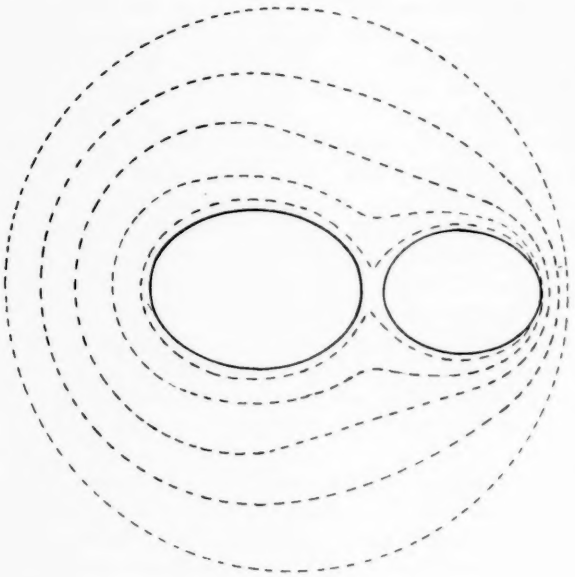


Fig. 4.—Arrangement of Equipotential Surfaces.

The lower part of Plate I is intended to give an idea of relative dimensions and distances in the system.

Though the problem of β Lyrae's marvelous behaviour cannot

be considered as more than begun as yet, the following assertions may nevertheless be regarded as pretty well established.

1. The photometric observations of β Lyrae's variability may be satisfactorily explained on the satellite theory.

2. The light fluctuations require an assumption of polar flattening and this requirement is met quite well on the hypothesis that the components are similar ellipsoids of revolution.

3. The common flattening is about 0.17 and aside from librations, the periods of rotation and revolution both equal 12.91 days.

4. The orbit is nearly circular and its plane passes through the solar system.

5. The brightness of the larger body viewed from without, is 0.4 that of the smaller.

6. The distance between centres is extremely small, approximately 1⅞ of the semi-major axis of the larger ellipsoid. They may even constitute a single figure of equilibrium (Poincaré).

7. The motion of the system's centre of gravity with respect to the Sun is very small.

8. The semi-major axis of the orbit of the companion is approximately 50 million kilometers.

9. The mass of the larger component is 21 times and that of the smaller 9.5 times the Sun's mass.

10. The densities of the two bodies are nearly equal and the mean density of the system is comparable with nebular density.

11. The best spectroscopic observations available to the writer contradict the photometric estimates in no essential particular.

12. The eccentricity of the orbit of the companion has increased considerably since 1855. A discussion of Lindemann's chief epochs derived from Plassmann's observations of 1893, which the writer cannot here take space to insert, indicate the same increase as is shown by a comparison of the values given by Argelander's curve and Belopolsky's spectrogrammes.

It is also worthy of note that Mr. Belopolsky's recent results published in *Ap. J.* for November are in general accord with those given here. He obtains for the orbital eccentricity the value 0.07, which is confirmatory of the above assertion of the writer, that the eccentricity has increased since 1855.

A curve constructed by Professor Pickering from 8000 photometric measures has just reached the writer and aside from the possible, though uncertain, suggestion of a period of about 1.2 days, just before and after Min. II, nothing would be certainly modified if Pickering's curve were substituted for Argelander's in

the above discussion, so far as can be judged without investigation, which may not be attributed to secular change of orbital eccentricity and periastron position. The general nature of the light fluctuations of this star is the same today as in Argelander's time. It should also be mentioned in this connection that Mr. Pannekoek has recently made an exhaustive investigation of the period of Beta Lyræ, and finds a positive correction to Argelander's value of 12.907834 days amounting to 0.000175 days. He also concludes that Argelander's epoch should be increased from 1855 Jan. 6.623 M. T. of Bonn to 1855 Jan. 6.604 M. T. of Greenwich.

January, '98,

UNIVERSITY OF ILLINOIS.

STARS AND MILKY WAY.*

FOR POPULAR ASTRONOMY.

I. STARS.

NOTE. All the questions proposed in this chapter are designed to be answered directly from observation or by data obtained from observation. The time throughout is Eastern Standard Time, civil date, unless the contrary is explicitly stated.

1. POINTS AND CIRCLES. 1. If the North Star is taken to mark the north pole of the heavens, how is the pole placed in reference to zenith and horizon?

2. How do the cardinal points obtained directly from the North Star differ from those fixed by the Circles?

3. What is the error of a north and south line located by the North Star?

4. On a given date what stars are taken to trace the path of the celestial equator?

5. How near the zenith does the celestial equator pass at a given hour? At what point does it intersect the horizon?

6. Does it remain fixed with regard to the horizon of a given place from week to week? From month to month?

7. By what stars is the ecliptic traced?

8. On a given night what is its meridian altitude and at what points does it intersect the horizon?

9. During two or three hours, what changes are noted in its position with regard to the horizon?

* From Chapter VIII, Laboratory Methods of Study for the Elements of Astronomy soon to be published by Mary E. Byrd, Observatory of Smith College, Northampton, Mass.

10. What changes are noted if two observations are made at the same hour of the evening, but in different months of the year?

11. What are the meridian altitudes of the ecliptic determined in the daytime by the Sun, and by a star on the following night?

12. What stars are employed in fixing the position of the vernal equinox? The autumnal equinox?

2. RISING AND SETTING. 1. When and where at a given place does a star rise if its declination is about 10° north of the equator?

2. How do the times of setting of two stars compare if one is about 20° north and the other 20° south of the equator?

3. Can a star be found rising at the east point of the horizon?

4. What is the greatest angular distance north or south of the east point at which a star is seen to rise?

5. At what intervening points is the rising of stars noted?

6. At what points along the western horizon are stars found to set.

3. VISIBILITY. 1. Can a bright star be followed at the place of observation till it sets, that is, till it actually reaches a distant horizon line?

2. If a star is of the third or fourth magnitude, at what height above the horizon does it disappear?

3. When, if ever, have you seen a star in the evening before sunset?

4. On a clear evening what star is seen first after sunset? How soon is it visible?

5. How long after sunset before sixth magnitude stars are visible? Does the presence of the Moon affect the time?

6. As seen with an opera glass, what is the difference in the appearance of a star that is well up toward the zenith and one that is about to set?

7. Does the transit tube affect the appearance of a star?

4. COÖRDINATES. 1. On a given night what is the altitude and azimuth of a star south of the zenith?

2. How much do these coördinates vary if observations are separated by an hour?

3. Under what conditions is altitude found to change rapidly and azimuth slowly?

4. If observations are made at one place on nights a week or two apart, does a particular star have the same azimuth at setting? Is the time of setting the same?

5. Is any variation found in the meridian altitude of the same star?

6. From altitude and azimuth observed with the Circles, what values are found by calculation for right ascension and declination?

7. What is the estimated right ascension and declination of a given star?

8. What is the estimated latitude and longitude of a given star?

9. If observations of a particular star are separated by several weeks, is any change detected in its right ascension and declination?

5. APPARENT MOTION. 1. If the diurnal path of a star has been located by making measures of its altitude and azimuth, is any change noted in the path a month or two later?

2. What is a star's hourly rate of motion in the diurnal path?

3. Having fixed the position of the "big dipper" with regard to the horizon, do you find after an hour or two that it has moved toward the eastern or toward the western horizon? Are like results obtained in October and in April?

4. What easier method than sitting up all night and watching with a telescope all day can you devise for determining the complete rotation of the big dipper?

5. What stars on a given night are found moving toward the eastern horizon?

6. In general toward what part of the horizon are stars moving?

7. By making careful maps of a particular constellation at different times, is it possible to detect any motion of the stars with regard to one another?

8. Judging from your own observations under what general statement is it possible to include the apparent motion of all stars in different parts of the sky?

6. LATITUDE. 1. What value for the latitude of the place of observation is obtained from a meridian altitude of the North Star?

2. What is the latitude derived from an altitude of this star when not on the meridian?

3. How can latitude be found by observing a star whose declination is zero?

4. What value for latitude is obtained by finding the meridian altitude of a star of any declination?

5. How can the altitude of two stars on opposite sides of the zenith be utilized in finding latitude?

7. TIME. 1. What is the hour-angle of a circum-polar star

when the line connecting it with the North Star appears to be parallel to the horizon?

2. How accurately can you tell sidereal time from β Cassiopeiæ?

3. What is the error of a common watch determined from the altitude and azimuth of a star measured with the Circles?

4. If the altitude only is measured, what error is found?

5. If two plumb lines are taken to fix the meridian, how accurately is the watch error found from the transit of a star?

6. As determined by two transits of a star, what is the difference in the length of the sidereal and the mean solar day?

8. COLOR AND BRIGHTNESS. 1. From your own observations, what color do you assign to each of the following stars?

(1) α Aquilæ
(2) α Aurigæ
(3) α Boötis
(4) α Canis Majoris
(5) α Canis Minoris
(6) β Orionis
(7) γ Orionis
(8) α Persei
(9) α Piscis Australis
(10) α Scorpii
(11) α Geminorum
(12) β Geminorum
(13) α Leonis
(14) α Lyræ
(15) α Orionis
(16) α Tauri
(17) β Tauri
(18) α Ursae Majoris
(19) β Ursae Majoris
(20) α Virginis

2. From among the stars of this list which are visible on any particular night, what pairs can be selected in which the two stars are nearly equal in brightness? What pairs where there is a marked contrast in brightness?

3. What pairs can be selected in which the two stars are alike in color? What pairs in which there is a marked contrast in color?

4. Which is the brighter, α or β Leonis? α or β Geminorum?

5. What is the brightest star seen during the year?

6. Among the stars visible in different seasons which do you rank second in brightness? Which third?

7. When brightest how does Algol compare with α Persei?

8. On the evening of a minimum, when is Algol found equal in brightness to 30 Persei? When equal to η and when to γ Persei?

9. When is o Ceti first visible with an opera-glass? When first visible to the naked eye?

10. When does this star reach a maximum in brightness?

11. Can you detect any variation in the brightness of the following stars?

(1) λ Tauri
(2) ε Aurigæ
(3) η Geminorum
(4) ζ Geminorum

9. DOUBLE STARS, CLUSTERS AND NEBULAE. 1. Can you see ζ Ursae Majoris double with the naked eye?

2. How does it look through an opera-glass?

3. In the following list of stars can you distinguish more than one with the naked eye? With the opera-glass?

(1) 15 Canis Venaticorum
(2) α Capricorni
(3) β Capricorni
(4) σ Cassiopeiæ
(5) υ Cassiopeiæ
(6) o Cygni
(7) α Libræ
(8) δ Lyræ
(9) ε Lyræ
(10) c Orionis
(11) ι Orionis
(12) θ Orionis
(13) π Pegasi
(14) ζ Scorpii
(15) μ Scorpii
(16) θ Tauri
(17) υ Tauri
(18) σ Tauri
(19) $\varkappa$ Tauri
(20) 80 Tauri

4. Can you see the nebula of Andromeda with the naked eye?

5. How does it look through an opera-glass?

6. How many stars can you see in the cluster of the Pleiades with the naked eye? What is the number counted with an opera-glass?

7. How many of the following star clusters and nebulæ are seen with the naked eye? How does an opera-glass change their appearance?

(1) Coma Berenicis.
(2) Præsepe.
(3) Orion Nebula.
(4) VI, 33, 34, Herschel near η Persei.
(5) VII, 2, Herschel, in Monoceros.
(6) 11 Messier, near λ Aquilæ.
(7) 13 Messier, between η and ζ Herculis.
(8) 34 Messier, not far from β Persei.
(9) 35 Messier, near η Geminorum.
(10) 36, 38 Messier, between θ and ι Aurigæ.
(11) 37 Messier, between θ Aurigæ and β Tauri.
(12) 41 Messier, not far from α Canis Majoris.

II. Milky Way.

10. Form and Diameter. 1. Is the arch of the Milky Way a part of a large or a part of a small circle?

2. At any particular point what is its diameter in degrees?

3. What are the greatest and least diameters noted?

4. At what point does a branch extend from the main arch? What is its length and diameter?

11. Varying Brightness. 1. How early in the evening and in what part of the sky does the first trace of the Milky Way appear?

2. At what hour is the whole arch seen as distinctly as artificial lights permit?

3. Where is the arch of light especially bright? Where is it pale?

4. What stars in Cassiopeia, if connected bound an especially bright spot in the Milky Way?

5. What stars connected bound a "coal sack" in Cepheus? What ones in Cygnus?

12. APPARENT MOTION. 1. In the latter part of September, about nine o'clock in the evening, how is the arch of the Milky Way placed with regard to the zenith?

2. What is the azimuth of each point at which it intersects the horizon?

3. How is it placed with regard to zenith and horizon about nine o'clock on an evening in January, in April, and in June?

4. What change is noted in the points of intersection after the interval of a month? What change in the highest point of the arch?

5. If observations instead of being taken a month apart are separated by two hours on the same evening, how does the position of the Milky Way change?

6. Do the stars in the Milky Way move with it, or are they left behind?

SUGGESTIONS AND ILLUSTRATIONS.

13. CARDINAL POINTS. Before permanent lines of reference are established (see Chapter II) it is well to fix the cardinal points approximately with the help of the North Star. A clear night should be chosen, and an hour when twilight or moonlight renders objects on the horizon easily visible. If then we face toward the North Star and mark out its vertical circle by sweeping downward from the zenith through the star to the horizon, the intersection of this circle with the horizon locates the north point.

To fix the south point, the right hand may be directed to the point just determined, and both arms extended to form a straight line. This line of direction prolonged to the horizon on the left marks the south point. The east and west points may be located in a similar manner by facing north. Several tests should be made before deciding upon the position of the cardinal points, permanent objects should then be chosen to mark them on the horizon, and sketches and descriptions entered in the notes.

14. CONSTELLATIONS. It is not incumbent upon astronomers to pay any heed to the constellations, but elementary students will find it helpful as well as pleasant to become familiar with the ancient grouping of the stars. It is well for them to form the habit of watching the principal constellations at about the same evening hour from month to month; to compare their meridian altitudes with those of the Sun and Moon at about the same date; and to associate their rising and setting with permanent marks on the horizon and with the different seasons of the year.

When individual constellations are taken up for detailed examination, it is important to identify the bright stars from sky to map, to make sketches with proper symbols for different magnitudes, and to fix in mind definite configurations. Thus we may think of Lyra as a parallelogram and triangle combined with a few outlying points.

METEROIC SHOWER OF NOV. 13, 1897.

We have been much interested in the paper recently published by William H. Pickering on the meteoric shower of Nov. 13, 1897, as number V, for volume XLI of the Annals of Harvard College Observatory, a copy of which has just come to hand.

Professor Pickering secured observations of this last shower of the Leonids in two ways: the visual and the photographic. He was assisted by O. C. Wendell, W. A. Garrison and a number of students from the University. His attention was given to photographic work at Blue Hill. The time used was the Eastern Standard, five hours west of Greenwich, England. The radiant point of the Leonids according to Denning is $\alpha = 9^h\ 58^m$ and $\delta = +\ 22°.9$, which lies within the "sickle," about half way between the stars γ and ϵ. The radiant point rose on the 13th at $10^h\ 33^m$ and crossed the meridian at $18^h\ 07^m$ at an altitude of $70°.2$. The night was favorable on the whole, although cold and windy.

At Cambridge, after 9^h, for the night, at least three observers steadily faced the eastern sky and one or two the western. At Blue Hill, after 10^h, two observers watched the eastern sky all night, but on account of the high wind the western sky was less carefully observed.

The whole number of meteors observed at Cambridge was 91. The first maximum came at $14^h\ 00^m$, the minimum following at about 15^h. A second maximum occurred at $16^h\ 30^m$, decreasing but a little till $17^h\ 30^m$, after which daylight soon ended observations.

Up to $14^h\ 15^m$ only 9 meteors were seen at Blue Hill. During the next half hour to $15^h\ 15^m$, 6 more; for the next half hour, 5 more; next half hour, 6; next, 10; next, 8; and, last, ending at $17^h\ 45^m$, 4. In all 48 were counted. Of the 32 whose times were noted 8 were Leonids, 8 came from other radiants, and the remaining 16 have no definite record. The greatest number seen in one hour at Cambridge was 17, at Blue Hill 18.

The Moon was full five days before the shower. It preceded the radiant by three hours in right ascension, and had the same declination. It therefore interfered with observations seriously, in obscuring faint meteors and in hindering photographic work.

Combining the work of both stations, it was found that the Leonids were but slightly brighter than the non-Leonids, the average magnitudes being 2.9 and 3.1, respectively. In regard to color, there was a smaller proportion of yellow to white among the Leonids than among the other meteors, showing that the Leonids are by no means all bluish or greenish, as is sometimes stated. Regarding the duration of visibility, that of the Leonid is slightly greater than that of the average meteor, but does not greatly exceed it. The duration of visibility of over one-half of the meteors averaged about one-half of a second.

The account given by Professor Pickering of the three bright meteors observed on the same evening is very important matter. We give part of the same in his own words:

"The three bright meteors above mentioned were only observed at Cambridge, and were seen in the eastern sky. The first one appeared at $12^h\ 10^m\ 03^s$. Its duration was 1^s, its magnitude -1, and its color bluish. The path was $37°$ long, its course was southeast, and when prolonged backwards passed about $15°$ northeast of the radiant point of the Taurids of November 20. The second meteor appeared at $13^h\ 46^m\ 59^s$. The evidence indicates that it may have been an Andromede. Its course, which was not plotted, was said to be about $5°$ long, and its magnitude -2. The third meteor appeared at $14^h\ 54^m\ 09^s$. Its motion was very slow, and it remained visible for about 20^s, leaving a trail which vanished in about 2^s. It was estimated to be as bright as Jupiter, and of a red color. Its course was due east, with a declination of $-31°$. It appeared in right ascension $6^h\ 43^m$, and disappeared in $8^h\ 49^m$."

"The paths of fifty meteors were plotted at Cambridge, and of thirteen at Blue Hill. In only two cases, however, was the path of the same meteor observed from both stations. In both of these cases the Blue Hill observation was made by myself, and although three more of my observations lay in the immediate vicinity of the radiant, they were unfortunately not seen in Cambridge. Nine meteor trails observed in Cambridge, all lying within twenty degrees of the radiant, were missed at Blue Hill, and at least one fairly bright meteor passed near the radiant, which was missed at both stations as we shall see later. These figures will give an idea of the number of meteors that probably appeared and were

missed by the various observers, even in a small and carefully watched section of the heavens."

"To compute the true paths of the two meteors observed at both stations, we have given the following data. Altitude of the Cambridge station, 25 meters. Altitude of the Blue Hill station, 190 meters. Distance between the two, measured upon the map of the United States Geological Survey, 18.81 km. Azimuth of Blue Hill from Cambridge, measured from the south towards the east, 3° 53′. Computed angular Altitude of Blue Hill above the plane tangent to the Earth at Cambridge, +0° 23′ 30″. From these figures we find the hour angle at Blue Hill as seen from Cambridge, to be 5° 42′ 30″, and its north polar distance 137° 05′ 30″. From a consideration of the position angle of the two stations as seen from the radiant point we find the corresponding position angle of displacement of any body situated near the radiant point, as seen from the two stations, at the hour angles and times given in the following table:

POSITION ANGLES OF DISPLACEMENT.

H.	Time.	P. A.	H.	Time.	P. A.
h.	h. m.	°	h.	h. m.	°
7	11 07	+42.3	3	15 07	+ 29.9
6	12 07	+42.2	2	16 07	+ 19.9
5	13 07	+40.6	1	17 07	+ 8.6
4	14 07	+36.8	0	18 07	− 5.1

The fundamental facts relating to the two meteors are given in the following table. The meteors are designated as I and II. The stations from which they were observed are indicated by their initials. Following the initial is given the time at which each meteor appeared. This is followed by the duration of its flight, its magnitude, and color, R standing for red, O for orange, and W for white. Next is given the position angle of its displacement as seen from the two stations. Lastly is given the hour angle and north polar distance at which it appeared and disappeared, taken from the charts on which the paths were plotted. To simplify the computation the Blue Hill observations are referred to a plane tangent to the Earth at Cambridge, and the hour angles at both stations are therefore computed with regard to the Cambridge meridian.

OBSERVATIONS OF METEORS I AND II.

Meteor.	St.	E. S. T.	Dur.	Mag.	Color.	P. A.	Appeared.		Disappeared.	
							H.	D.	H.	D.
		h m s	s			°	°	°	°	°
I	C	12 32 03	2	1	R	41.5	83.0	69.0	91.0	79.5
I	B	12 32	1.5	2	O	"	83.5	68.5	86.5	70.5
II	C	14 17 19	—	2	W	35.8	55.0	69.5	49.5	74.0
II	B	14 16 ±	2	3	W	"	55.5	67.0	55.5	67.0

The heavy lines in Figures 1 and 2 show their paths. The fine parallel lines give the position angle of their displacement. In the case of I, the position angle of the points of appearance agrees almost exactly with its theoretical value. The points of disappearance are, however, discordant. It has therefore been decided

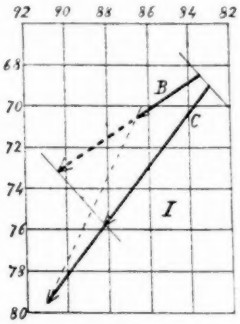


Fig. 1.

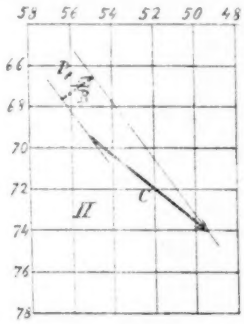


Fig. 2.

to pass the line indicating their relative position angle through the point lying half way between them, and to consider that the points of disappearance lay at the intersections of this line with the tracks of the meteors prolonged. Meteor II was not well seen at Blue Hill. It was recorded as stationary, its point of appearance being indicated in the figure by a cross. In order to make its course intersect the fine lines drawn through the ends of the course observed in Cambridge, a dotted arrow has been passed through the cross perpendicular to these lines. This leaves the distance of the point of appearance very uncertain, but does not seriously affect the point of disappearance, on account of its comparative proximity to the observers.

Adopting for the hour angles and polar distances the corrected values of these quantities given upon the two charts, and the

hour angle and polar distance of each station as seen from the other, a brief computation gives the distance of the meteor from Cambridge at the times of its appearance and disappearance. By means of a chart which had previously been constructed, it was possible to read off the angular altitude of a body as seen from Cambridge, given its hour angle and polar distance. Given then the altitude and distance of the meteor as seen from Cambridge, its elevation above the surface of the Earth was readily determined. According to these computations Meteor I appeared at a height of 650 km. or 406 miles, and disappeared at a height of 69 km. or 43 miles. Distance at time of disappearance 313 km. or 196 miles. Meteor II appeared at a height of 291 km. or 182 miles, and disappeared at a height of 77 km. or 48 miles. Distance at time of disappearance 119 km. or 74 miles. I place little confidence in the values of the heights at which these meteors appeared, but believe that the other results are more trustworthy. The errors introduced I believe are due in part to the inexperience of some of the observers, and in part to the great distance of the meteors at the time of their appearance, together with the comparative proximity of the stations.

(*To be Continued.*)

PLANET NOTES FOR JULY.

H. C. WILSON.

Mercury is coming out from behind the Sun, and will not be visible to the unaided eye during the month. On July 27 at 4 A. M., Central Standard Time, Mercury will pass very close to the star Regulus.

Venus is getting a little higher in the west each night at Sunset, and her brightness will increase during July in the proportion of 70 to 85. Her phase is gibbous and diminishing from .81 to .71 during the month. Venus will pass Regulus about one degree to the north on July 13. Venus and the Crescent Moon will be in conjunction July 21 at $5^h\ 19^m$ A. M.

Mars, during July, will pass through the constellation Taurus. The declination of Mars is now well toward the north, and will increase during the next two months; but the planet does not reach the meridian until the Sun is high in the morning, so that observations can only be obtained in the morning twilight. The apparent diameter of Mars is now about 5″.

Jupiter is moving slowly eastward in Virgo, and will be very close to the star η on the 13th. This will be the last month in which we may expect to obtain good views of Jupiter during this year.

Saturn is now in best position for evening study, being near the meridian about 9 o'clock. The rings are open almost to their widest extent, and all the marked features are distinguished with ease in moments of good seeing. The

wonderful system of rings and satellites will afford the amateur many an hour of pleasant and profitable study. Saturn is in Scorpio, a few degrees north of Antares.

THE CONSTELLATIONS AT 9 P. M., JULY 1, 1898.

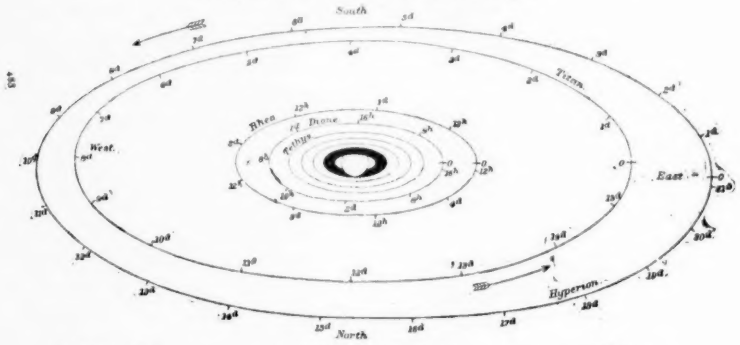
Uranus is in the same constellation, west of the star β. Some of our students, a few nights since, easily recognized the planet by its green disc, as seen with a five-inch telescope.

Neptune, having just passed superior conjuction, is not in position to be observed.

Saturn's Satellites.

[The diagram indicates the position of the outer satellites of Saturn at intervals of 1 day, after greatest eastern elongation. The ephemeris below gives the Central Standard times when the satellites will be at either eastern elongation (E) or western elongation (W), or, in the case of the outermost ones, inferior conjunction, south of the planet, (I) and superior conjunction, north of the planet, (S).]

APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, at opposition in 1898, as seen in an inverting telescope.



I. MIMAS.

Period $0^d\ 22^h.6$

		h		
June	2	1.6	A. M.	W
	3	12.2	"	W
	3	10.8	P. M.	W
	4	9.4	"	W
	5	8.1	"	W
	11	12.5	A. M.	E
	11	11.1	P. M.	E
	12	9.7	"	E
	13	8.3	"	E
	14	6.9	"	E
	19	11.3	"	W
	20	9.9	"	W
	21	8.5	"	W
	27	11.6	"	E
	28	10.2	"	E
	29	8.8	"	E
	30	7.4	"	E

II. ENCELADUS.

Period $1^d\ 8^h.9$

		h		
July	1	6.6	P. M.	E
	3	3.5	A. M.	E
	4	12.4	P. M.	E
	5	9.2	"	E
	7	6.1	A. M.	E
	8	3.0	P. M.	E
	9	11.9	"	E
	11	8.8	A. M.	E
	12	5.7	P. M.	E
	14	2.5	A. M.	E
	16	8.3	P. M.	E
	18	5.2	A. M.	E
	19	2.1	P. M.	E
	20	10.9	"	E
	22	7.8	A. M.	E
	23	4.7	P. M.	E
	25	1.6	A. M.	E
	26	10.5	"	E

II. ENCELADUS Con.

Period $1^d\ 8^h.9$

		h		
July	27	7.4	P. M.	E
	29	4.3	A. M.	E
	30	1.1	P. M.	E
	31	10.0	"	E

III. TETHYS.

Period $1^d\ 21^h.3$

		h		
July	1	5.0	P. M.	E
	3	2.3	"	E
	5	11.6	A. M.	E
	7	8.9	"	E
	9	6.1	"	E
	11	3.4	"	E
	13	12.7	"	E
	14	10.0	P. M.	E
	16	7.3	"	E
	18	4.6	"	E
	20	1.9	"	E
	22	11.2	A. M.	E
	24	8.5	"	E
	26	5.8	"	E
	28	3.2	"	E
	30	12.5	"	E
	31	9.8	P. M.	E

IV. DIONE.

Period $2^d\ 17^h.7$

		h		
July	3	12.2	A. M.	E
	5	5.9	P. M.	E
	8	11.6	A. M.	E
	11	5.2	"	E
	13	10.9	P. M.	E
	16	4.6	"	E
	19	10.2	A. M.	E
	22	3.9	"	E

IV. DIONE Con.

Period $2^d\ 17^h.7$

		h		
July	24	9.6	P. M.	E
	27	3.3	"	E
	30	9.0	A. M.	E

V. RHEA.

Period $4^d\ 12^h.5$

		h		
July	5	2.9	P. M.	E
	10	3.2	A. M.	E
	14	3.6	P. M.	E
	19	3.9	A. M.	E
	23	4.3	P. M.	E
	28	4.7	A. M.	E

VI. TITAN.

Period $15^d\ 23^h.3$

		h		
July	2	2	A. M.	W
	6	2	"	S
	9	10	P. M.	E
	13	10	"	I
	17	12	MIDN.	W
	21	12	"	S
	25	8	P. M.	E
	29	8	"	I

VII. HYPERION.

Period $21^d\ 7^h.6$

		d			d	
July	5.0	E	July	20.5	S
	10.4	I		26.4	E
	15.2	W		31.7	I

VIII. JAPETUS.

Period $79^d\ 22^h.1$

June	23.0	I	July 13.2 W
Aug.	2.7	S	

Jupiter's Satellites for July.

Central Standard Time.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I. III.

II. IV. No Eclipse

Configuration at 8h 00m for an Inverting Telescope.

Day.	West.	East.
1	2·	○ 1· 3· 4·
2	3· 2·	○ 4· 1●
3	3· 1·	○ 4· 2·
4	3· 4·	○ 2· 1·
5	4· 2· 1·	○ 3●
6	4·	○ 1· 3· 2●
7	4· 1·	○ 2· 3·
8	4 2·	○ 1· 3·
9	4 2 3· 1	○
10	4 3· 1·	○ 2·
11	3· 4	○ 1 2·
12	2· 1· 3	○ 4●
13		○ 1· 4 3 2●
14	1·	○ 2· 3· 4
15	2·	○ 1· 3· 4·
16	2 3· 1	○ 4·
17	○ 1· 3·	○ 2· 4
18	3	○ 1 2· 4·
19	2· 3 1·	○ 4·
20	2	○ 4· 1 3
21	1 4	○ 2· 3
22	○ 2· 4·	○ 1· 3
23	4· 2· 1 3·	○
24	4· 3·	○ 1· 2
25	4 3	○ 2· 1●
26	4 2· 2 1·	○
27	4 2·	○ 1 3
28	4 1·	○ 2· 3
29	○ 2·	○ 4 1· 3·
30	2 1	○ 3· 4
31	3·	○ 2 1· 4

The Moon.

		Phases.	Rises. (Central Standard time at Northfield; Local Time 13m less.)		Sets.	
			h	m	h	m
July	3	Full Moon	8	10 P. M.	5	18 A. M.
	10	Last Quarter	11	21 "	2	0 "
	18	New Moon	4	29 A. M.	7	51 P. M.
	26	First Quarter	1	25 P. M.	10	59 "

Occultations Visible at Washington.

Date 1898.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle from N pt. °	EMERSION. Washington M. T. h	m	Angle from N pt. °	Duration. h	m
July	4	σ Capricorni	5.6	9	44	42	10	44	284	1	0
	4	π Capricorni	5.1	14	29	23	15	26	280	0	57
	4	B.A.C. 7044	7.0	16	2	334	16	5	328	0	3
	6	θ Aquarii	4.4	11	59	90	13	1	208	1	2
	10	101 Piscium	6.3	12	54	100	13	43	203	0	49
	20	o Leonis	3.8	8	29	89	9	16	318	0	47
	30	B.A.C. 6369	6.2	8	53	129	9	43	208	0	50

Phenomena of Jupiter's Satellites.

Central Standard Time.

		h	m					h	m			
July	1	9	11 P. M.	I	Tr. In.	July	17	7	34 P. M.	I	Tr. In.
		10	27 "	I	Sh. In.			8	45 "	I	Sh. In.
	2	9	44 "	I	Ec. Re.			9	49 "	I	Tr. Eg.
	3	7	10 "	I	Sh. In.		18	8	5 "	I	Ec. Re.
	5	9	15 "	III	Oc. Re.		22	7	22 "	II	Sh. In.
	9	8	15 "	I	Oc. Dis.			7	37 "	II	Tr. Eg.
	10	7	52 "	I	Tr. Eg.		23	7	36 "	III	Tr. Eg.
		9	5 "	I	Sh. Eg.			9	30 "	III	Sh. In.
	12	8	53 "	IV	Oc. Dis.		26	7	23 "	I	Sh. Eg.
	13	8	8 "	II	Oc. Dis.		29	7	45 "	II	Tr. In.
	15	7	14 "	II	Sh. Eg.		31	7	30 "	II	Ec. Re.
	16	8	0 "	III	Sh. Eg.						

Ec. Dis. = Eclipse disappearance; Ec. Re. = Eclipse reappearance; Oc. Dis. = Occultation disappearance; Oc. Re. = Occultation reappearance; Sh. In. = Ingress of shadow upon disc of planet; Sh. Eg. = Egress of shadow from disc; Tr In. = Ingress of satellite in transit across disc of planet; Tr. Eg. = Egress of satellite.

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

1898.

U CEPHEI.

	d	h
Aug.	1	21
	4	9
	6	21
	9	9
	11	21
	14	8
	16	20
	21	20
	26	20
	31	19

ALGOL.

	d	h
Aug.	11	22
	14	19
	17	16
	20	13
	28	14

δ LIBRAE.

	d	h
Aug.	4	11
	6	19
	11	11
	13	19
	18	11
	20	18
	25	10
	27	18

U CORONÆ.

	d	h
Aug.	5	9
	8	20
	15	18
	22	16
	29	13

U OPHIUCHI.

Every 10th min.

$P = 20^h.1$

	d	h
Aug.	9	0
	17	10
	25	19

W DELPHINI.

	d	h
Aug.	4	15
	9	10
	23	20
	28	16

RS SAGITTARII.

	d	h
Aug.	1	17
	6	13
	8	23
	11	9
	13	19
	18	15
	23	11
	25	21
	30	17

Maxima and Minima of Long Period Variables.

1898 September.

MAXIMA.

		m	day
103	T Andromedæ	8	14
268	X Sculptoris	9	12:
845	R Ceti	8	18
1582	S Tauri	9.5	4?
1894	T Columbæ	7.5	19
2445	W Monocerotis	9	21:
2530	V Canis minoris	10	9
2815	U Geminorum	9.3	18:
3128	R Pyxidis	8	12:
3418	R Carinæ	5	13
3425	X Hydræ	8.5	15
3567	V Leonis	8.5	26
5194	V Bootis	7	6
5438	Y Libræ	8.5	16:
5583	X Libræ	9.5	12
5593	W Libræ	10	15
5677	R Serpentis	6.5	15
5761	Z Scorpii	9	9
5950	W Herculis	8	3
6050	RS Scorpii	7	7:
6903	T Sagittarii	8	3
7234	R Capricorni	9.5	3:
7252	W Capricorni	10.5	6
7260	Z Aquilæ	9	14:
7431	S Delphini	9	20

MAXIMA, CONT.

		m	day
7455	U Capricorni	10.5	6
7456	RR Cygni	8.5	28
7482	U Pavonis	9.5	1
7560	R Vulpeculæ	8	29
8153	R Lacertæ	9	20

MINIMA.

110	S Tucanæ	< 11	—
434	S Piscium	< 14	2
466	U Piscium	15	15
1855	R Aurigæ	12.5	27
2735	U Canis minoris	12.5	22
3264	W Cancri	< 13	—
5037	RR Virginis	< 14	—
5321	S Lupi	< 12	—
6062	RR Scorpii	9.5	18:
6608	RV Sagittarii	12	—
7045	R Cygni	< 14	2
7220	S Cygni	< 14	5
7299	U Cygni	10.5	28
7404	R Microscopii	12	24
7448	W Aquarii	9.5	22:

The authorities for the above ephemeris are the same as in the previous issues of this year.

U GEMINORUM. Rev. J. H. Earp, of Kennett Square, Penn'a., sends me the following observation of this star, made with a 2½ inch refractor:

1898 May 9.62, G. M. T., 9^m.8 seeing good.

This is in satisfactory agreement with the observations published in the June number of POPULAR ASTRONOMY, and it is hoped that it will be continued, and that other amateurs will also take it up.

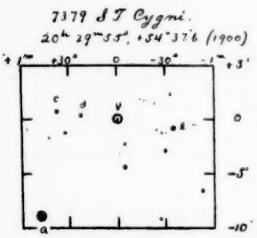
The next maximum of this star will probably occur about August 1. If it does not occur before that time, it will probably be far enough from the Sun to be seen with a large telescope. It is very important to keep track of the number of the epoch, and it is hoped that some one having the use of a good equatorial will begin watching this star as soon as it becomes visible in the morning.

Hawthorn, Penn'a., ZACCHEUS DANIEL.
1898 June 7.

Remark on Mr. Daniel's Note.—It is quite unlikely that the next maximum of U Geminorum can be observed, as the star will be too near the Sun. The star is situated within about 1° of the ecliptic, in Right Ascension 7^h 49^m, which the Sun reaches July 17. The latest evening maximum on record seems to be that observed by Mr. Dearden 1895 June 14, 33 days before conjunction with the Sun. In the last seven years the shortest interval between maxima has been about 65 days, the mean interval 86 days, and the longest about 100 days. Counting from the maximum May 6, the next might be expected any time between July 10 and August 14. As August 19 is 33 days after conjunction, the chances for visibility seem very slight.

SS CYGNI. Mr. F. E. Seagrave, of Providence, R. I., has favored me with a copy of his observations 167 in number, of this star made with an 8¼-inch equatorial on 109 dates in 1897. His observations were made by Argelander's method, and will be published in the Annals of the Harvard College Observatory. They agree very closely with the results given in the May number of POPULAR ASTRONOMY, and in addition furnish some needed details of the maxima occurring in the winter and early spring of 1897. They make it seem probable that the rise from normal, 11.3 magnitude, to the 9th magnitude, sometimes requires 48 hours, instead of always occurring in 24 hours or less.

The May maximum of this star was well observed. Mr. Daniel compared it on 25 nights from May 1 to June 6; Mr. Sperra on 8 nights from May 16 to 30. On account of cloudy weather I secured only 4 observations. The maximum was typical "long" one, the rise beginning May 17.3, 9.35 magnitude was passed May 17.8, the maximum was passed May 22.2, and it reached normal light June 6.4, thus remaining above normal 20.1 days. The last interval between maxima was 60.6 days, between the times of passing 9.35 magnitude, 57.4 days, and the duration of normal light 45 days. This destroys the suspected relation between the length of the maximum and the following normal period.



ESPIN'S VARIABLE 7379 ST CYGNI. Particulars in regard to this star were given in the June number, page 248, but the chart was poorly engraved and misleading, therefore a new one is presented here. At this writing, June 16, the variable is still bright, but little fainter than the 9th magnitude.

RV HERCULIS. This new variable, which is charted in POPULAR ASTRONOMY, Vol. V, page 326, proves to have a very faint minimum. It was invisibe June 13, in the 12-inch refractor and also in the 24-inch reflector of the Yerkes Observatory, and so must have been decidedly fainter than the 14th magnitude The minimum probably occurs in June or July.

COMET NOTES.

Rediscovery of Encke's Periodic Comet.—This comet was found within 5′ of its predicted place, on the night of June 11, by Mr. John Tebbutt at Windsor, New South Wales. The observed position was as follows:

Greenwich M. T.	R. A.	Decl.
June 11.8435	$6^h\ 53^m\ 29^s.0$	$+11°\ 34'\ 00''$

Ephemeris of Encke's Comet.

[Continued from last number].

	α			δ			log r	log Δ
	h	m	s	°	′			
July 1	8	49	51	− 21	23.9		9.9435	9.4708
5	9	41	31	− 32	19.7		9.9760	9.4402
9	10	50	14	− 42	0.7		0.0055	9.4429
13	12	10	18	− 47	58.8		0.0325	9.4772
17	13	26	1	− 49	52.2		0.0572	9.5310
21	14	26	17	− 49	9.3		0.0800	9.5927
25	15	10	40	− 47	23.5		0.1011	9.6547
29	15	43	1	− 45	24.2		0.1207	9.7140

Re-discovery of Wolf's Periodical Comet.—Yesterday morning I re-discovered this periodical comet with the 36-inch refractor very close to the place given by Thraen's ephemeris in the *Astronomische Nachrichten* (3481.) This morning I observed it with the 12-inch telescope and found it an easy object with this instrument. The position at the time of re-discovery was:

	Mt. Hamilton Mean Time.	Apparent R. A.	Apparent Decl.
1898 June 16	$15^h\ 5^m\ 21^s$	$2^h\ 16^m\ 18^s.91$	$+19°\ 42'\ 44''.1$

This comet was first discovered by Max Wolf at Heidelberg, Sept. 17, 1884. At its next return it was re-discovered by Spitaler at Vienna, May 1, 1891, and at this apparition remained visible until the end of the following March.

The elements of its orbit resulting from the observations made during the first and second apparitions have been investigated by Thraen, and the thoroughness and accuracy of his work is well shown in the close agreement of the present observed and computed places of the comet. W. J. Hussey.

Lick Observatory, University of Cal.

June 18, 1898.

The *Astronomische Nachrichten*, No. 3481, gives the following ephemeris for the comet:

Berlin M. T. 1898.	R. A. h.	m.	s.	Decl. °	′
June 11	1	59	58	+ 19	18.0
19	2	23	48	+ 19	51.3
27	2	47	43	+ 20	8.7
July 1	2	59	39	+ 20	11.2

New Comet Coddington Discovered Photographically.—A bright comet was discovered by its image upon a photograph taken by Mr. Coddington at Lick Observatory. The following telescopic observations have been received from the observers at Lick Observatory:

Observer.	Greenwich M. T.	R. A. h	m	s	Decl. °	′	″
Hussey	June 11.7220	16	24	45.9	− 25	14	20
Coddington	June 12.7288	16	21	34.1	− 25	52	43
Coddington	June 13.7593	16	18	05.0	− 26	31	48

The following elements and ephemeris computed by Hussey and Coddington at Lick Observatory from observations made June 11, 13, and 15, have been received by telegraph:

Elements of Comet c 1898.

T = Sept. 10.31, 1898 Greenwich mean time.
α = 229° 28′
υ = 73 59
i = 71 18
q = 1.7685

Ephemeris.

Greenwich M'dn't.		α			δ			Light.
June	20	15	54	32	− 30	41		1.07
	24	15	40	20	− 32	59		
	28	15	26	24	− 35	07		
July	2	15	12	52	− 37	05		1.05

Elements and Ephemeris of Comet *e* 1898 (Perrine).—The following elements have been deduced using the Mount Hamilton observations of June 14, 15 and 16:

T = 1898 Aug. 17.400 Greenwich M. T.
ω = 196° 45′ 48″
Ω = 260 5 55 } Ecliptic and mean equinox of 1898.0.
i = 69 42 23
log q = 9 87026

Residuals, Obs.—Comp.

$\Delta\lambda'$	+ 2″
$\Delta\beta$	− 5

Constants for the Equator of 1898.0.

$x = r\,[9.58263]\sin(170° 2′ 56″ + v)$
$y = r\,[9.99997]\sin(\ 81 25 18 + v)$
$z = r\,[9.96567]\sin(171 39 24 + v)$

Ephemeris for Greenwich Mean Midnight.

1898	True α h m s	True δ ° ′	log Δ	log r	Br.
June 20.5	4 2 54	+ 57 15.4	0.284	0.118	1.18
24.5	4 26 24	55 56.4	0.276	0.099	1.33
28.5	4 48 48	54 20.1	0.268	0.080	1.51
July 2.5	5 9 59	+ 52 26.8	0.261	0.060	1.72

Comet *e* is about as bright as a tenth magnitude star, and has a central condensation; but there is no stellar nucleus. This comet is not quite as bright as comet *b* (March 20) at present. Comet *e* is now west and north of the latter, but is overtaking it, and towards the end of June the two comets will be within one-half degree of each other. The orbit of comet *e* presents considerable resemblance to that of comet *b*, and also those of 1684 and 1785 I.

C. D. Perrine and R. G. Aitken.

Lick Observatory, University of California.
1898, June 18.

Comet of Giacobini.—June 21 we received the telegraphic message of the discovery position of a new comet by Giacobini, of Nice, France. Date of discovery was June 19, 12h 11m 22s.56. The right ascension, 20h 26m 48.8s, and declination, −21° 27′ 6″. Daily motion in right ascension is westward 11m 28s, in declination, southward 20′.

Search Ephemeris for Tempel's Periodic Comet (1867 II).

[Continued From Last Number.]

	α h m s	δ ° ′	log. Δ	log. r
July 1	12 10 39	+7 34.1	0.3330	0.3437
3	13 8	7 6.7		
5	15 41	6 39.0	0.3397	0.3419
7	18 17	6 11.2		
9	20 57	5 43.2	0.3462	0.3402
11	23 40	5 14.8		
13	26 25	4 46.4	0.3526	0.3385
15	29 13	4 17.7		
17	32 4	3 48.9	0.3589	0.3369
19	34 58	3 20.0		
21	37 55	2 50.9	0.3650	0.3353
23	40 55	2 21.7		
25	43 57	1 52.3	0.3709	0.3338
27	47 2	1 22.9		
29	50 10	0 53.3	0.3767	0.3324
31	53 20	+0 23.6		
Aug. 2	12 56 32	−0 6.1	0.3823	0.3310

GENERAL NOTES.

From the notices of Comets in this issue it will easily appear that this kind of business has greatly improved during the last month.

Owing to absence from home on a short vacation trip the first part of this month the next number of this publication may be a few days late.

Dr. H. C. Wilson takes an outing during the present month. He will spend some time at the Yerkes Observatory, and he will also visit the Cincinnati Observatory, where he studied practical astronomy, years ago, under Professor Ormond Stone, who is now Director of the Leander McCormick Observatory, at the University of Virginia.

An Ultra-Neptunian Planet.—In our last number something was said of the existence of an ultra-Neptunian planet, and that some astronomers have supposed the possibility on account of the behavior of certain comets that remotely indicate a family relation caused by an unknown planet in the depths of space far beyond the planet Neptune. From a private letter we are helpfully reminded by a friend that this idea, pretty elaborately worked out, belongs to Professor George Forbes, of Glasgow (now a noted electrician), who published papers on the subject in 1879-80. One of those papers will be found in *The Observatory*, Vol. III, pp. 439-446. We should have called attention to this source of information before.

Conference of Astronomers and Physicists.—At the dedication of Yerkes Observatory, in the autumn of 1897, a successful meeting of astronomers and physicists was held in connection with that occasion. All present were so much interested and profited that it was agreed that similar conferences should be continued in some way. After consultation with various astronomers, it has been decided to hold the next meeting at Harvard College Observatory on Thursday, Friday and Saturday, August 18, 19 and 20, 1898. These days were selected because the American Association for the Advancement of Science will meet in Boston during the week, beginning Monday, Aug. 22, on the occasion of the fiftieth anniversary of its foundation. This arrangement will enable visiting astronomers to attend this meeting and avail themselves of the special rates which have been obtained from hotels and railroads. Full preparations are being made for these meetings, and visitors may expect a series of most profitable conferences.

Zodiacal Light.—In a carefully written article on the Zodiacal Light, by E. W. Maunder, *March Monthly Notices*, 1898, the following paragraph, pertaining to color, will interest our readers:

"The brightest portion of the light showed a delicate, but unmistakable, color—a faint, pale yellow, with, perhaps, the slightest inclination to the green, rather than to the orange. The contrast between this tint and the steely blue of the Milky Way was only less pronounced than the contrast between the broad areas of diffused luminosity of the Zodiacal Light and the granulation of the Galaxy. Yet they had one feature in common. I felt convinced that in the lights as in the Galaxy, there were dark lanes and rifts, though in the former these lane,

are far more difficult objects, and I was not able to lay down the course of any of them with sufficient accuracy. Two lines of somewhat rapid fading, if not positive dark lanes, were suspected at right angles to the ecliptic, near longitudes 16° and 25°, respectively."

Report from Royal Observatory, Greenwich.—The report of the Astronomer Royal to the Board of Visitors of the Royal Observatory, Greenwich, read at the annual visitation, 1898, June 4, has been received very promptly. It is an interesting paper, giving a brief outline of the year's work at this great Observatory, under the direction of W. H. M. Christie, Astronomer Royal. A few extracts from it are of general interest:

"The correction to the tabular obliquity of the ecliptic, from solar observations of 1897, is + 0″.21. The discordance between the results from the summer and winter solstices is + 0″.12, indicating that the mean of the observed distances from the pole to the ecliptic is too small by 0″.06. The apparent correction from the observations of the Sun to the right ascensions of the clock stars is + 0ˢ.065."

"The mean error of the Moon's tabular place (computed from Hansen's lunar tables, with Newcomb's corrections) is — 0ˢ .142 in right ascension, and + 0″.27 in north polar distance, deduced from 95 observations. These are equivalent to an error of — 1″.97 in longitude and + 0″.16 in ecliptic north polar distance."

"The preparation of the new ten-year Catalogue of Stars, 1887–1896 is making good progress. The right ascensions and north polar distances for all the years have been reduced to 1890. The means have been taken for the clock stars, and for 732 stars in the Berliner Jahrbuch, which were completed in advance of the rest of the catalogue, in order that the results might be communicated to Dr. Auwers, who wished to use them in the preparation of a fundamental catalogue. Copy of the catalogue for the press has been made as far as the entry of the names of the stars, precessions, secular variations and proper motions."

"In this catalogue the equinox of the 1872 nine-year catalogue (carried on with the Struve-Peters precession) is adopted, although the observations of the Sun appear to give a correction of 0ˢ .046, as it is considered that this change is largely due to the difference of personality in observations of the Sun to changes in observers."

"The large number of circumpolar observations in this catalogue, and in the year 1897 furnish material for the discussion of the co-latitude and refraction."

* * * * *

"The Staff at present is thus constituted, the names of each class being arranged in alphabetical order:

Chief Assistants—Mr. Cowell, Mr. Dyson.

Assistants—Mr. Hollis, Mr. Lewis, Mr. Maunder, Mr. Nash, Mr. Thackery.

Second Class Assistants—Mr. Bryant, Mr. Crommetin.

Clerical Assistant—Mr. Outhwaite.

Established Computers—Mr. Bowyer, Mr. Davidson, Mr. Edney, Mr. Furner, Mr. Rendell and one vacancy.

The two Second-Class Assistants will be replaced by high grade established computers as vacancies occur. The whole number of persons regularly employed at the Greenwich Observatory are 52."

Photographic Spectrum of the Aurora.—Various attempts have been made at this Observatory to photograph the spectrum of the aurora. In 1886

on several occasions long exposures were given to plates during bright auroras, but no result was obtained. On April 1, 1897, Mr. Edward S. King succeeded in obtaining a photograph, in which four bright lines were visible; but uncertainty existed regarding their wave lengths. The exposure was 147 minutes. During the bright aurora of March 15, 1898, he obtained a photograph, showing two bright lines. The exposure was 141 minutes. The brightest of these lines extends in wave length from about 3892 to 3925, and the wave length of the second is 4285. Assuming the two brighter lines photographed in 1897 to be identical with these, the four lines on that plate have the wave lengths 3862, 3922, 4288 and 4694. The first of these lines is very faint.

The errors of measurement of these lines do not exceed one or two units, but much greater uncertainty exists in the reduction owing to difficulties in comparing them with the lines of the solar spectrum which was photographed upon the same plate. Probably the two auroras gave different spectra. That in 1897 was taken with a wide slit, but the images of the lines were well defined on the edges and of equal width, so that the line 3922 was probably really narrow and coincident with the edge of greater wave length of the line 3892 to 3925. The spectroscope used was not especially designed for photographing faint surfaces, and it is hoped that better results may be obtained with a new instrument, now in course of construction. As is the case with all results announced in these circulars, it is expected that full details will be published later in the Annals of the Observatory.

EDWARD C. PICKERING.

March 23, 1898. Circular No. 28.

Harvard College Observatory.

The November Meteors.—On the night of November 13, 1897, 91 meteors were observed at the Harvard College Observatory, and 47 meteors at an auxiliary station 12 miles south, the Blue Hill Meteorological Observatory. A discussion of these observations, by Professor W. H. Pickering, will be found in the Annals of this Observatory, Volume XLI., No. V. A much greater display of meteors is expected next year, and it is very important that a continuous watch should be kept during the two or three days in which the Earth is passing through the denser portion of the meteor stream. This can only be done by establishing a series of stations in various longitudes, so that during the entire time one or more of these stations shall fulfill the conditions that the radiant point shall be above the horizon and the Sun below. Correspondence is invited with astronomers and others willing to participate in this work, especially with those who will be in the less frequented longitudes. If the weather is favorable, and the plan here proposed is carried out satisfactorily, it is expected that all the observations will be discussed here and published in the Annals of this Observatory. To secure the best results a uniform plan of work is essential. Maps and forms of record will be sent to all who early signify their readiness to take part in this work. The radiant point of the meteors indicated by the cross in the accompanying map* will not rise in this latitude until $10^h\ 30^m$, and twilight will interfere at about $5^h\ 30^m$ in the morning. As the shower sometimes begins before the predicted date, a watch should be kept on November 11 and 12, from 11 to 1 o'clock, and if many meteors are seen the observations described below, for November 13, should be made on these nights, and also on the nights following the shower.

Each observer is requested to devote his attention to the region within 25° of the radiant point, and included in the map, and to send the following data regarding his observations: — Name of observer, location of station, postoffice ad-

dress, time of beginning and ending of observations, interruptions by clouds or other causes, condition of sky, as clear, hazy, passing clouds, etc.

The observations most desired are those required to determine the frequency of the meteors. They are of extreme simplicity, and need only care, system and perseverance. Once an hour, or better once every half hour, observe and record the time during which ten meteors appear. This is most easily done by noting the time by a watch and at exactly the beginning of a minute looking at the sky, giving it undivided attention and counting the meteors seen, not including those appearing outside of the region covered by the map. If great numbers of meteors appear it may be better to count a larger number, as twenty, or even fifty. If the interval between the meteors is long the number to be counted may be reduced. These observations should be repeated until dawn, or over as long an interval as possible. Between these observations the observer may rest, or may make special observations of individual meteors. Thus, when a meteor is seen, record the hour and minute, the brightness on a scale of stellar magnitudes, — 2, equals the brightness of Jupiter or Sirius; 0, Arcturus or Vega; 2, the Pole Star; 4, the Pleiades; 6, the faintest star visible; the color, B = blue, G = green, Y = yellow, W = white, and R = red; the class, L = Leonid, if path prolonged would pass through center of map, N = other meteors. Thus L 5 Y, $12^h\ 26^m$, indicates that a Leonid, magnitude 5, yellow in color, was seen at $12^h\ 26^m$. Find by trial beforehand how many seconds are required to make each record. Again, the path of each meteor may be marked upon the map by noting its position in relation to the adjacent stars. Such work can be done equally well elsewhere, and should not interfere with the hourly count mentioned above.

EDWARD C. PICKERING.

May 30, 1898, Circular No. 31.
Harvard College Observatory.

A Daylight Meteor.—On Friday, 3d inst., about 1 o'clock P. M., a large and brilliant meteor was seen here. It is described as about a foot† in diameter, with a tail, or train, about six feet long. Both meteor and train glittered like silver in the Sun. Though the meteor was quite low and not far away, no rushing noise nor sound of an explosion was heard The meteor moved towards the northwest and at an angle which must soon have brought it to the ground. Unfortunately, intervening buildings prevented the exact spot of its fall from being seen, and a subsequent search over several acres of ground disclosed nothing.

R. M. M'CREARY.

Greensburg, Pa.

The Large Refractors of the World.—Lists of existing large telescopes have appeared previously in other places, but for obvious reasons such lists require occasional revision. The present table has been constructed with the help of the various makers who have been kind enough to send us details of their creations, so that there is reason for thinking it complete. With reference to the fourth column, with heading "Maker," the name of the firm who made the object-glass is given; in such cases as it is known that the amounting was made by a second firm, a number is affixed, signifying respectively: (1) Warner and Swasey;

* To be found with the memoir referred to above.
† An unusual way of telling the size of celestial objects. Circular measure, as degrees, minutes, or seconds should be used. A "foot in diameter" means different things to different people. [Ed.]

(2) Gautier; (3) Repsold; (4) Ransome and Simms; (5) Saegmuller; (6) Brunner; (7) Cooke and Sons; (8) Cavignato.—*The Observatory*, No. 267.

Aperture in inches.	Focal length in feet.	Institution.	Maker.	Date of Erection.	Remarks.
40.0	62.0	Yerkes Obs'y, Wis., U. S. A.	Alvan Clark (1).	1897	Visual.
36.0	57.8	Lick Obs'y, Cal., U. S. A.	Alvan Clark (1).	1888	Visual.
33.0	49.2	Lick Obs'y, Cal., U. S. A.	Alvan Clark (1).	....	Photographic corrector for 36 in.
32.5	53.0	National Obs'y, Meudom.	Henry Bros. (2).	1891	Visual.
31.1	39.4	Astrophysical Obs'y, Potsdam.	.....	....	Photographic. Not Erected.
30.3	52.6	Bischoffscheim Obs'y, Nice.	Henry Bros. (2).	1889	Visual.
30.0	42.0	Imperial Obs'y, Paulkova.	Alvan Clark (3).	1882	Visual.
28.9	..	National Obs'y, Paris.	Martin.		
28.0	28.0	Royal Obs'y, Greenwich.	Sir H. Grubb (4).	1894	Visual and Photographic.
27.0	34.0	Imperial Obs'y, Vienna.	Sir H. Grubb.	1878	Visual.
26.0	26.0	Royal Obs'y, Greenwich.	Sir H. Grubb.	1897	Pho'c. Pre'd by Sir H. Thompson.
26.0	32.5	Naval Obs'y, Washington, U. S. A.	Alvan Clark (1).	1871	Visual.
26.0	32.5	Leander McCormick Obs'y, Va.	Alvan Clark.	1874	Visual.
25.0	..	Cambridge University Obs'y.	T. Cooke & Sons.	1868	Visual. Pre'd by Mrs. R. S. Newall
24.4	52.2	National Obs'y, Meudon.	Henry Bros. (2).	1891	Photographic.
24.0	11.3	Harvard Coll., Cambridge, U. S. A.	Alvan Clark.	1894	Pho'c doub't Pre'd by Miss Bruce
24.0	22.6	Royal Obs'y, Cape of Good Hope	Sir H. Grubb.	1897	Pho'c. Pre'd by Mr. F. McClean.
24.0	31.0	Lowell Obs'y, Arizona, U. S. A.	Alvan Clark.	1895	Visual. { These telescopes on
23.6	59.0	National Obs'y, Paris.	Henry Bros. (2).	1889	Visual. { the same mountain
23.6	59.0	National Obs'y, Paris.	Henry Bros. (2).	1889	Pho'c. { form the Equatorial
23.0	32.0	Halsted Obs'y, Princeton, U.S.A	Alvan Clark.	1881	Visual. { Coude.
21.8	..	Etna.	Merz.		
21.2	..	Buckingham Obs'y.	Buckingham & Wragge		
20.5	..	M. Porro, Private Obs'y, Italy.	M. Porro.		
20.5	28.0	Chamberlin Obs'y, Col., U. S. A.	Alvan Clark (5).	1891	Visual.
20.0	..	Manila Obs'y, Philippine Isles	Merz.	1892	
19.7	41.2	Astrophysical Obs'y, Potsdam.	.....	....	Guiding telescope for the 31.3 in.
19.1	23.0	Imperial Obs'y, Strassburg.	Merz (3).	1880	Visual.
19.1	23.0	Milan Obs'y, Italy.	Merz (3).	....	Visual.
18.5	27.0	Northwestern Univ., Ill., U. S. A.	Alvan Clark.	1863	Visual.
18.1	29.5	National Obs'y, La Plata.	Henry Bros. (2).	1890	
18.0	26.3	Lowell Obs'y, Mexico.	Alvan Clark.	1894	Visual. Coude.
18.0	..	Flower Obs'y, Philadelphia.	Brashear (1).	1896	Visual.
18.0	..	Vander Zee Obs'y.	Fitz.		Visual.
18.0	22.6	Royal Obs'y, Cape of Good Hope	Sir H. Grubb.	1897	Visual.
16.5	26.2	Bischoffsheim Obs'y, Nice, France	Henry Bros. (2)	1889	Visual. Coude.
16.5	26.4	Imperial Obs'y, Vienna.	Henry Bros. (2)	1890	Visual. Coude.
16.5	29.5	Obs'v of Jesuit Fathers, Zi-ka-Wei	Henry Bros. (2)	1897	Photographic. { Same mount-
16.5	23.0	Obs'v of Jesuit Fathers, Zi-ka-Wei	Henry Bros. (4)	1897	Visual. { ing.
16.0	..	Goodsell Obs'y, Minn., U. S. A.	Brashear (1).	1891	Visual.
16.0	..	Lowe Obs'y, Cal., U.S.A.	Alvan Clark (1)	1880	Visual.
16.0	..	Professor Max Wolf, Heidelberg	Brashear.	....	Photographic doublet.
16.0	..	Professor Max Wolf, Heidelberg.	Brashear.	....	Photographic doublet.
15.7	5.3	National Obs'y, Meudon.	.....	....	For eclipse studies.
15.7	6.0	Harvard Coll. Obs'y, Cambridge	Merz.	....	Photographic.
15.6	10.3	Washburn obs'y, Wis., U. S. A.	Alvan Clark.	1878	Visual.
15.5	..	Dr. V. Cerulli, Peramo, Italy.	T. Cooke & Sons.	1887	Visual. Formerly belonged to Mr. Wigglesworth
15.3	..	National Obs'y, Paris.	Henry Bros	1882	Visual.
15.1	..	Royal Obs'y, Edinburgh	Sir H. Grubb.	1873	Visual. Pre'd by Lord Crawford.
15.0	..	Madrid Obs'y.	Merz.		
15.0	15.0	Dr. Huggins's Obs'y, Tulse Hill.	Sir H. Grubb.	1870	Visual.
15.0	..	National Obs'y, Rio de Janeiro.			
15.0	15.0	Tacubaya Obs'y, Mexico	Sir H. Grubb.	1880	Visual.
15.0	29.0	National Obs'y, Paris.	Lerebours (6).		
15.0	15.0	Stonyhurst Coll. Obs'y, Lancashire	Sir H. Grubb.	1893	Visual.
15.0	..	Milan Obs'y.			
15.0	15.0	Mississippi University.	Sir H. Grubb	1893	Visual.
15.0	22.0	Harvard Coll. Obs'y, Cambridge.	Merz.	1849	Visual.
15.0	22.5	Imperial Obs'y, Poulkova, Russia	Merz & Mahler (3)	1839	Visual.
15.0	15.0	Mr. Dunn's Obs,y Maidenhead.	Sir H. Grubb.	1893	Visual.
15.0	15.0	Mr. Dunn's Obs'y, Maidenhead.	Sir H. Grubb.	1894	Photographic.
14.9	..	The Obs'y, Odessa, Russia.	Merz.	1884	
14.9	23.0	Bischoffsheim Obs'y, Nice, France.	Henry Bros (2).		
14.9	22.4	National Obs'y, Bordeaux, France	Merz (2).	1886	Visual.
14.9	20.0	National Obs'y, Brussels.	Merz (7).	1877	
14.6	..	Lisbon Obs,y.	Merz & Mahler.		
13.8	19.7	Fational Obs'y, Besancon, France.	Henry Bros (2).	1887	Visual.
13.5	25.5	Col. Cooper's Ob., Markree Irel'd	Cauchoix.	1834	
13.5	..	Hamilton Coll., Clinton, N. Y.	Spencer & Eaton.		
13.4	18.3	Catania Obs'y, Etna.	Merz.	1891	

The Gender of the Moon.—In English, French, Italian, Latin and Greek the Moon is feminine; but in all the Teutonic tongues the Moon is masculine. Which of the twain is its true gender? We go back to the Sanskrit for an answer. Prof. Max Muller rightly says ("On the Religions of India"): "It is no longer denied that for throwing light on some of the darkest problems that have to be solved by the student of language, nothing is so useful as a critical study of Sanskrit." Here the word for the Moon is Mas, which is masculine. Mark how even what Hamlet calls "words, words, words," lend their weight and value to the adjustment of this great argument. The very Moon is masculine, and, like Wordsworth's child, is "father of the man."

Pola Jahrbuch of Observations for 1897. Volume II of the Pola Jahrbuch of observations for 1897 has just been received. It is a fine, large octavo volume of 168 pages with plates and illustrations setting out work in meteorology mainly, very well.

Transcendental Space. Professor Charles H. Chandler, Professor of Mathematics, Ripon College, some months ago prepared a thoughtful paper on Transcondental Space and read the same before the Wisconsin Academy of Sciences, Arts and Letters. The same will be found in Vol. XI of its transactions.

Catalogue of the Magnitudes of 1,081 Stars by A. Stanley Williams.—We have recently received from A. Stanley Williams, 20 Hove Park Villas, Sussex, England, a copy of his Catalogue of the Magnitudes of 1,081 Stars, lying between — 30° declination and the South Pole, from observations made in the years 1885-6, during the course of a voyage to Australia, round the Cape of Good Hope and back by the Red Sea, and including a stay of two months in Australia. The plan of this work was to select seven groups of comparison stars from the Harvard Photometry, and to make several hundred observations of the brightness of stars north of south declination 30°, to acquire practice in the method before leaving England.

The atlas used was Proctor's smaller star atlas with the addition of all the other stars contained in all the larger maps published by the Society for the diffusion of useful knowledge. So nearly all the stars contained in Lacaille's original catalogue of 1942 stars, and lying south of — 30° declination were thus included. These stars of the Williams catalogue have been identified by comparison with the maps of the Uranometria Argentina with the exception of a few not contained in that work.

The observations for this catalogue were made with an opera glass; by "steps" of eye-estimates on the scale of tenths of magnitude, as used in the Harvard photometry. The catalogue columns are: star number, right ascension, declination, for 1875, constellation, letter designating star, Lacaille number of star, and then three columns for magnitude: Uranometria Argetina, Southern Meridian Photometry and finally William's number for the same. The catalogue has 21 pages of useful notes pertaining to the stars catalogued.

PUBLISHER'S NOTICES.

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All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

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